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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

WORK OF THE EXPERIMENT STATIONS OF THE BUREAU OF MINES

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Most of the technologic work of the Bureau of Mines is carried on at eleven Experiment Stations located as follows: Bartlesville, Oklahoma; Berkeley, California; Birmingham-Tuscaloosa, Alabama; Minneapolis, Minnesota; New Brunswick, New Jersey; Pittsburgh, Pennsylvania; Reno, Nevada; Rolla, Missouri; Salt Lake City, Utah; Seattle, Washington; and Tucson, Arizona. The following paragraphs give brief descriptions of the work being done at each of these stations.

A summary of titles will be found on page 23 .

PETROLEUM EXPERIMENT STATION, BARTLESVILLE, OKLAHOMA.

a. Investigation of methods of handling producing wells. A study is being made to determine the most satisfactory methods of producing oil from wells under different field conditions.

b. Investigation of mud fluid for oil and gas well use. Mud fluid is used in drilling oil wells to aid the cutting action of the bit and to hold back gas and water in the formations penetrated. The properties of different materials are being studied to obtain fluids that are best suited for different conditions.

c. Separation of wax from lubricating wax distillates. Much oil that could be made into satisfactory lubricants is now burned as fuel because no entirely successful method has been developed for removing the wax. Present methods are being investigated as a starting point toward the development of more practical processes.

d. Study of crude petroleum. Until the composition of crude petroleum is known, the most efficient use can not be made of it and its products. Therefore the compounds of crude petroleum are being isolated and studied.

e. Shooting of oil wells. Data are being assembled on the practices of shooting wells to increase the production of oil. These data include kinds of explosives used, methods of detonation, and the amount of explosive for various formations.

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f. Methods of increasing the recovery of oil. Engineers have estimated that present methods of oil recovery allow 80 to 90 per cent of the oil to remain underground. To increase the recovery from the sands, air lift, repressuring with gas and air, water flooding and other measures are being studied in the field and laboratory.

g. Investigation of sulphur compounds in crude oil. The biggest single problem in petroleum refining is the elimination of sulphur. Data in regard to sulphur compounds in petroleum are of the greatest importance. Attempts are being made to isolate these compounds, and new methods for their detection and estimation have been worked out.

h. Investigation of the use of gas for lifting oil. A fundamental study of the principles involved in the use of gas and air lift methods is being directed toward determining installations which will lift the oil efficiently.

i. Study of the flow of natural gas through pipe lines. The flow of gas through transmission lines is being studied to determine the most economic types of installations.

j. Study of Oklahoma asphalt. Methods are being developed for segregating the true asphaltic deposits from other materials that are somewhat similar in character but are unsuitable for highway construction.

k. Study of disposal of oil field waters. The contamination of streams by the saline waters that are produced with petroleum is being studied. The possibility of obtaining certain commercial salts from these waters opens a way to convert a waste into an economic asset.

l. Study of evaporation losses of petroleum and gasoline. Results obtained by the commercial application of methods and equipment for the reduction of losses by evaporation are being studied. These investigations are being presented to the petroleum industry in a way that enables the operator to choose the method and equipment best suited to his particular problems.

m. Chemical treatment of light petroleum distillates. Experimental studies were made on the chemical treatment of gasoline and similar products and the conclusion was reached that isolating and treating fractions containing undesirable substances is cheaper and better than treating the gasoline as a whole.

n. Safety work. The cause of accidents and methods for their prevention in the Mid-Continent oil field are studied and information disseminated.

FIELD OFFICES

In addition to the work at Bartlesville, petroleum studies are also conducted at Dallas, Texas; Laramie, Wyoming; and San Francisco, California. Oil shale studies are carried out at Boulder and Rifle, Colorado. Since the work of these field offices is closely associated in subject matter with that at Bartlesville, a report on their problems is inserted at this point.

Dallas, Texas

Engineering reports on producing fields. Engineering studies of the methods of oil production in different fields, the mapping of producing sands, the methods used to prevent water encroachment, etc., are studied in producing areas, and recommendations leading to more efficient recovery of oil on the basis of previous similar studies are made to the operators. Fields where engineering reports have been or are being prepared include Seminole (by Bartlesville staff), Powell, Wortham, Putnam and Texhoma-Gose.

Laramie, Wyoming

a. The deposition of paraffin in oil wells - the cause, effect, and measures used to overcome the resulting difficulties. In certain districts, paraffin deposits often clog the face of sands and the casing in wells. The cause of such clogging has been studied and some preventative methods have been devised.

b. Laboratory study of physical characteristics of paraffins and waxes. Data on the physical characteristics of paraffins and waxes occurring in crude oil have been obtained as an aid in understanding the cause for an elimination of the deposition of paraffin in wells.

c. Study of methods for producing flowing wells in the Rocky Mountain region. A study is being made of methods for reducing the amount of gas produced per barrel of oil. The solution of this problem will decrease the cost of production.

San Francisco, California

a. Salvages in the oil industry. Millions of dollars are expended annually in the United States in the purchase of new mechanical equipment used in the oil industry, without proper attention being paid to the possibility of reconditioning used material. A study of this subject and dissemination of the information gained should be of great value to the oil industry.

b. Engine tests on lubricating oils. A series of dynamometer tests has been made on various lubricating oils. The influence of viscosity, volatility, and other properties of lubricants is being studied in relation to consumption of both fuel and lubricating oil in internal combustion engines.

c. Methods of producing oil wells in California. An engineering study is being conducted on methods of oil production with particular reference to conditions which are characteristic of California, such as deep well drilling and pumping.

d. Bibliography of petroleum and allied substances. To meet the demands of the oil industry and libraries, a bibliography covering petroleum, natural gas and allied substances is prepared monthly and annually.

e. Safety in the natural gas gasoline industry. Information regarding safe and unsafe practices in this industry is being collected and will be published by the Bureau.

f. Thermal decomposition of oil-shale kerogen. The chemical reactions involved in the formation of shale-oil are being studied in the hope of securing information regarding the origin of petroleum.

Boulder and Rifle, Colorado

a. Investigations of experimental retorts and development. Oil shale retorts are investigated and production data obtained whenever possible. Such data lead to proper selection of equipment for specific conditions.

b. Refining study and analytical distillation of shale-oil. Analytical distillations are made on shale-oils to obtain information regarding their composition. The effect of various refining agents and of different methods of distillation on the composition of the oil can thus be determined and methods developed which produce the maximum amount of desirable products.

c. Assay retort studies. The Bureau has developed an assay retort for oil-shale in which samples of shale can be tested for oil content, and in which the conditions most favorable for maximum oil yield can be determined.

d. Study of nitrogen compounds in oil-shale and shale-oil. The kind and amount of nitrogen compounds present in oil-shale and shale-oil and their value as by-products are being determined.

e. Extraction and analysis of kerogen. Unchanged kerogen (the substance producing shale-oil) is being extracted from the shale, and its characteristics and relation to crude oil are being studied.

f. Weathering tests on oil-shales. The effects of weathering on the amount and quality of shale-oil produced from representative American shales is being studied.

g. Effect of inert gases on production of oil from oil-shale. These tests are being conducted in an effort to increase the quality and quantity of the shale-oil.

h. Experimental refining of shale-oil. Experiments are conducted to develop the best methods for refining shale-oil after it is secured from the shale.

PACIFIC EXPERIMENT STATION, BERKELEY, CALIFORNIA

a. Reduction of metal oxides. Equilibrium diagrams for the reduction of different metal oxides by carbon or reducing gases are being worked out. These results supply fundamental data heretofore lacking and greatly needed in working out new and improving present methods of refining various oxide ores to their metals.

b. Reduction of cuprous oxides. The equilibrium composition of gases resulting from the reduction of cuprous and cupric oxide to copper is being determined at different temperatures. This is urgently needed in the work of the Bureau of Mines on improving copper smelting methods.

c. Specific heats of oxides and sulphides. Data on the specific heats of the common ore minerals are used for calculating metallurgical heat balances in the treatment of these minerals and in calculating other data from which reactions can be predicted and equilibrium constants at different temperatures calculated. These have not been determined over the temperature range required in modern metallurgy. The Bureau's work is supplying this need.

d. Heats of formation of oxides and sulphides. More fundamental data not now available are being secured from these experiments, the results of which can be interpreted into heat conservation in various metallurgical processes.

SOUTHERN EXPERIMENT STATION, BIRMINGHAM-TUSCALOOSA, ALABAMA

a. Beneficiation of low-grade bauxite. There are at present many low grade bauxite deposits containing gangue material, especially silica, iron and titanium, which makes them objectionable for use as a source of aluminum. This study will lead to the development of methods of treatment for removing the objectionable impurities.

b. Beneficiation of low-grade phosphate ores. A similar problem exists in the phosphate industry. Experiments are being conducted which will lead to commercial processes for making available low grade phosphate deposits and eliminate certain wastes now occurring in the operation of existing deposits.

c. Coal washing problems in Alabama. Many of the Alabama coals are of a grade which require washing to reduce the ash content sufficiently to compete on the open market with the higher grade coals. The Bureau of Mines is conducting experiments in coal washing with the hopes of enlarging the field of usefulness of many Alabama coals.

NORTH CENTRAL EXPERIMENT STATION, MINNEAPOLIS, MINNESOTA

a. Separation of manganese, iron and phosphorous in high-phosphorous spiegel. For several years the Minneapolis Station of the Bureau of Mines has been investigating the metallurgical problems connected with the use of the manganiferous iron ores of Minnesota with the ultimate aim of making this country independent of imported ferro-grade manganese ores in time of national emergency. This problem is one phase of the larger investigation.

b. Resistance offered to flow of gas by columns of irregular solids. The efficiency of the blast furnace process depends to a large extent upon contac between gas and solid. The distribution of gas through the stock column is controlled by the relative resistance of various portions of the charge. This resistance is being carefully measured and the results interpreted as far as possible in improved practices in the distribution of raw materials in the furnac

c. Transfer of heat from a moving gas stream to a column of irregular solids. The Bureau of Mines is studying the transfer of heat from a moving gas stream at varying temperatures and rates of flow to beds of solid particles differing in size, density and heat conductivity. The results will be applicable to a number of commercial processes, chiefly the blast furnace.

d. Kinetics of iron ore reduction. Experiments are being conducted to determine the influence of gas composition, pressure, temperature, size of ore particles and rate of gas flow upon the ore reduction reactions. Such data should lead to improvements in blast furnace practice.

e. Comparative desulphurizing power of blast-furnace slags containing small percentages of barium oxide. It has been suggested that the addition of small percentages of barium oxide to blast furnace slags will materially increase their desulphurizing power. This is being checked experimentally.

f. Plant observations on the reactions in the iron blast-furnace. From accurate scientific measurements of the gas compositions, pressures, velocities, etc., at different points of the blast furnace under operating conditions many fundamental data on the effect of various furnace practices have been obtained. These studies have led to improvements in the past and are being continued.

NONMETALLIC MINERALS EXPERIMENT STATION, NEW BRUNSWICK, NEW JERSEY

a. Production and use of metallurgical limestone. A study has been made of the requirements regarding size and quality of limestone for different metallurgical purposes and at the same time of the quarry problems connected with their production. Such correlation of the producers' and consumers' problems will lead to more economic methods of production and utilization.

b. Occurrence, mining and milling of mica. The present methods of securing and treating mica under different natural conditions have been studied and more efficient methods of ore treatment and grinding developed.

c. Application of the wire saw in slate quarrying. It is said that 75 to 90 per cent of the gross production in the slate industry is wasted by the present quarry methods. Tests of the wire saw in several slate quarries have shown that much of such waste can be eliminated. The work is being extended to different slate producing regions.

d. Digest of literature on Stassfurt and Alsatian potash. At the present time great interest is being shown in the United States in the development of a domestic potash industry. For that reason the literature in regard to the foreign deposits is being abstracted and whatever helpful information it may contain is being secured. This is being applied to laboratory studies of our own potash minerals.

e. The concentration and treatment of potash ores. A chemical study is being made of the methods of concentration and purification of the potash minerals found in commercial quantities in the drill cores from the southwest. Commercial processes of treatment are also being developed.

f. A field study of the utilization of greensand. Much greensand occurs in readily available deposits in New Jersey and other states. A study is being made of the possibilities of commercial utilization of these deposits as a source of potash.

g. The effect of anhydrite in cement retardation. Report of investigation No. 2705 on calcium sulphate retarders for Portland cement has aroused much interest in this work. The present study is on the effect of fineness of anhydrite on retardation and the effect of different anhydrites.

PITTSBURGH EXPERIMENT STATION, PITTSBURGH, PENNSYLVANIA

Coal and Coal Products Research Section

Analytical Laboratory

a. Miscellaneous analytical work Much analytical work arises in connection with studies conducted by the Bureau of Mines. Materials analyzed include furnace slags, clinkers, ores, minerals, dusts, explosive residues, drill cores, boiler scales, etc. Several hundred determinations a month are made on such material.

b. Coal ash fusibility as related to clinker formation. In the past there has been no entirely satisfactory method of predicting the clinkering quality of a coal, although coal ash fusibility has been regarded as somewhat of an indication. In the present problem the analytical laboratory has made determinations of the fusibility of coal ash and correlated the results so obtained with the clinkering of the coal under furnace conditions, as determined by the Fuel Section.

Microscopical Laboratory

a. Microscopic studies of coal. The microscopic study of thin sections of coal has shed much light on the question of its origin by showing the components of different ranks of coal and coal of different physical properties. Furthermore, certain correlations are possible on this basis.

b. Chemistry of decay in relation to peat and coal formation. The principles underlying coal formation and the origin of certain constituents in the coal are being carefully studied.

c. Relation between composition and oxidizability of coal. A systematic series of samples, representing the various stages of coalification from peat to anthracite, are being examined microscopically and chemically to determine which constituents are responsible for spontaneous combustion.

Coal Carbonization Laboratory

a. Spontaneous combustion of coal. The sensitivity of various coals and coal constituents has been determined. The physical factors involved in the spontaneous combustion of coal have also been studied.

b. Determination of reactivity of coke in air, carbon-dioxide and water vapor at various temperatures. The relative ease of ignition and rate of combustion of coke have been determined in the past by various methods. These methods have been studied to correlate the results. Information has also been secured on the relation of the physical properties and method of manufacture to coke reactivity.

c. Oxidation of sub-bituminous coal at low temperatures. The internal structure of the molecule of the main mass of coal by the isolation of various parts of a typical sub-bituminous coal is to be determined. This problem is being carried out by British cooperation.

d. Survey of methods for determining gas and coke making properties of coals. Several methods are now in use for testing the value of a coal for carbonization purposes. Unfortunately some of these do not give results comparable to commercial practice. The Bureau of Mines is studying the value of these various tests and hopes to arrive at a practical moderate scale test method.

Organic Chemistry Laboratory

a. Constitution of low temperature tar. Almost nothing is known regarding the chemical compounds found in tar resulting from the low-temperature carbonization of coal. With this latter process becoming increasingly important a knowledge of the products formed is highly desirable and even necessary before cost sheets can be prepared for commercial operations.

Physical Chemistry Laboratory

a. Production of methanol. The personnel of the Coal Carbonization laboratory, the Organic Chemistry Laboratory, and the Physical Chemistry Laboratory, are cooperating on several problems regarding the production of synthetic motor fuels. The production of such fuels abroad has reached an important stage of development and American attention has recently been drawn to them by the purchase of certain patents by several American oil companies. Little is known, however, of the intimate details of these foreign processes. The Bureau of Mines has been actively engaged in similar research, chiefly on the production of methanol from carbon monoxide and hydrogen.

Health Laboratory Section

a. Miscellaneous gas analysis. In connection with many investigations conducted by the Bureau of Mines, especially field studies in coal mines, investigations after explosions or fires, places thought to contain some harmful gas, etc., gas samples are collected. These are analyzed and the results interpreted in the light of past experience.

b. Miscellaneous pathological studies. It is frequently necessary to make pathological studies in connection with other problems. Such work includes toxicity data, pathological changes under various conditions, etc.

c. Routine tests of gas masks and dust respirators. As new or improved masks and respirators come on the market, it is desirable to test them for safety and efficiency.

d. Physiological effect of various dusts on animals. The Bureau has been interested for a number of years in the effect on men of industrial dusts encountered in mining operations or factories. Data regarding a dust composed of but one mineral will give fundamental information. Hence, experimental work is being conducted on the effect of certain mineral dusts on animals.

e. Experimental effect of oxygen upon animals. Men doing mine rescue work are compelled to breathe high oxygen concentrations over long periods of time. In order to determine the effect of such exposure, animals were confined in atmospheres of 95 to 98 per cent oxygen under various conditions for various intervals of time and the effects noted.

f. Disposal of waste waters from mines. Recently considerable attention has been directed to the question of stream pollution by acid mine waters. The Bureau of Mines is gathering data on this subject and attempting to devise feasible methods of preventing such pollution.

g. Sealing abandoned mines and determining the cause of alkalinity in others. The Bureau of Mines is gathering information concerning the effect on the composition of mine drainage of sealing abandoned mines and portions of mines so as to exclude air. Certain results indicate that this may result in a decrease in acid water in the overflow.

h. Pathology of carbon monoxide poisoning. The Bureau of Mines has been a pioneer in studying carbon monoxide and the emergency treatment for such poisoning. However, up to the present time we have but little knowledge of the pathological changes attending it. Such information will assist in developing better treatment.

i. Relative toxicity of methyl chloride, ethyl chloride, methyl bromide and ethyl bromide. These compounds are being used or proposed for use as refrigerants. Knowledge of their toxicity, should they escape into the air, is important.

j. Temperature and humidity investigation. Information regarding the physiological reactions attending periods of work at high temperatures and humidity together with such work followed by rest periods under temperature conditions more favorable to comfort, is being obtained. The relation between the heat generated by the body, evaporation and comfort is also being studied.

k. Carbon monoxide recorder. During the past three years the Pittsburgh Station of the Bureau of Mines has developed an instrument for recording extremely minute concentrations of carbon monoxide in air. Work on the improvement of this apparatus and the extension of its usefulness is still in progress.

l. Occluded gases in coal as affecting inflammability of its dust. The gas absorption power of coal and the influence of various absorbed mine gases on coal dust explosions is being determined.

m. Warning agents for manufactured gas. In cooperation with the American Gas Association, the Bureau of Mines is studying the chemicals which might be added to gaseous fuels to warn of their presence in air by sensory action.

n. Sulphur dioxide in air. Wire screens of various compositions are being exposed to atmospheric conditions over long periods of time. To correlate the resulting corrosion with atmospheric composition, the sulphur dioxide content of the air is being determined daily.

o. Catalysts for automobile exhaust. Catalysts have been suggested as a means of eliminating the carbon monoxide hazard from automobile exhaust gases. Certain existing catalytic materials are being tested for efficiency in this capacity.

Explosives Section

a. Tests of explosives to determine their permissibility for use in coal mines. It is well recognized that not all explosives can be safely used in gaseous coal mines. Consequently the work of the Bureau in determining the permissibility of explosives is highly important.

b. Analysis of explosives and explosive materials. In connection with the research problems of this section, it is necessary to analyze many explosives and explosive materials.

c. Collecting and testing field samples of permissible explosives. In order to maintain the standard of permissible explosives, samples are collected in the field and checked against those submitted by the manufacturers.

d. Factors influencing the nature and quantity of poisonous gases liberated by explosives under mining conditions. The Bureau is determining the amount and composition of products of detonation of explosives under field conditions, with special reference to the poisonous and inflammable gases produced. At the same time, the effect of different factors met under actual mining conditions on these products of detonation is studied.

e. Determination of limit charge curves for permissible explosives in varying gas-air mixtures. Information is being secured regarding the charge limit gas composition curves of methane-air and natural gas-air mixtures, using explosives of different kinds and in varying quantities with different types of detonation and stemming.

f. Investigation of explosions due to explosives. By studying the various catastrophes resulting from explosions it is hoped to develop better methods for handling explosive materials.

g. Photographic study of the process of ignition of gas-air mixtures by explosives. Fundamental data on the mechanism of ignition and the manner of propagation at the time and immediately following actual ignition are being obtained.

h. Investigation of new explosives and of new components for explosive mixtures. New explosives and new components for explosives mixtures are frequentl being proposed and often adopted by the manufacturers. These are studied and passed upon by the Bureau. Glycol dinitrate has recently been the subject of such an investigation and is now accepted as a component of permissible explosives in substitution for part of the nitroglycerin.

i. Effect of carbon dioxide, nitrogen and helium on the limits of inflammability of carbon monoxide and hydrogen. Information has been secured regarding the amount of oxygen that must be present to cause hydrogen and carbon monoxide when diluted with inert gases to propagate flame. These data will be useful in considering whether the gases behind seals in mine fires and the detonating gases from explosives are inflammable and within what limits.

j. Determination of the temperature attained by the products of detonation of explosives. The temperature of the flame produced by detonation of explosives is believed to be one of the factors affecting the liability of ignition of inflammable mixtures by explosives. Calculated temperatures are probably in error due to lack of data on specific heats at high pressures and temperatures. Direct determination of the temperature is highly desirable.

k. Effect of confinement and nature of stemming and tamping on the charge limits of explosives. The effect of various methods of loading and kinds of stemming on the safety of explosives is being determined by gallery tests.

l. Velocity of detonation across a gas-gap between two cartridges of explosives. The velocity of propagation of detonation across a gap between two cartridges of explosives when the gaps are filled with various gases is being studied.

m. Metal mine explosives and blasting methods. The types of explosives in use under different mining conditions and the corresponding methods used in blasting are being studied to obtain information regarding the best explosive and blasting practice under particular conditions.

n. Development of analytical testing methods. In order to keep the laboratory at its highest efficiency, new methods suggested by others are tested and evaluated and, when necessary, original methods devised.

o. Relation between oxygen balance and explosive properties of eight samples of forty per cent gelatin dynamite. The explosive strength and gaseous products of detonation of a series of eight dynamites of varying oxygen balance are being determined.

Fuels Section

a. Refractory service survey in boiler furnaces. In the past we have been uninformed in regard to the conditions to be withstood by boiler furnace refractories. This study of temperature, gas, dust, coal and slag compositions will show the conditions existing within the furnace for which proper refractories must be developed.

b. Soot remover and soot prevention compounds. Products advertised as the above have been tested to ascertain whether the manufacturers' extraordinary claims are justified.

c. Heat flow meters for furnace walls. In connection with many investigations of the Fuels Section it is necessary to know the flow of heat through furnace walls. A meter suitable for measuring the high temperature losses in kilns and furnaces is being developed.

d. Tests of secondary air devices for domestic furnaces. Tests are being made of the value of appliances to admit secondary air to the combustion space of heating furnaces.

e. Coal ash fusibility as related to clinker formation. The correlation of the amount, type, and composition of clinkers from a furnace with the chemical investigation of fusibility of coal ash, mentioned under the Coal and Coal Product Section, is being carried out.

f. Determination of relative availability of cokes for use in domestic heating furnaces. A standardized burning test including ease of starting, overall combustibility, secondary air requirements, refuse loss, clinkering trouble, attendance requirements and effect of size of coke pieces, is being devised and various cokes tested by such standards.

g. Rating of low pressure heating boilers. The American Society of Heating and Ventilating Engineers has proposed a code for the rating of low pressure boilers. The application of this code is being tested, details of conducting the test developed, the influence of different fuels determined, and the effect on the rating caused by varying some of the limits specified in the code studied.

Metallurgical Section

a. Study of the cause and control of abnormality in case carburized steel. Ability to control the abnormality of case carburized steel will lead to the production of a better product.

b. Equilibrium between iron, manganese and sulphur. The factors affecting the desulphurization of pig iron by manganese, such as time, temperature, concentration of manganese and sulphur, presence of other elements, effect of slag, etc., are being studied.

c. Physical chemistry of steel making. In cooperation with the Carnegie Institute of Technology and an Advisory Board from the metallurgical industry, a five-year program on this subject was outlined. It includes work on the following problems of fundamental importance to the steel industry.

d. Distribution of iron oxide between slag and metal. The equilibrium constants of this fundamental physico-chemical reaction which occurs in the processing and refining of steel are being studied and determined.

e. Formation and identification of non-metallic inclusions. Many troubles from faulty steel are due to non-metallic inclusions. The Bureau is studying the mechanism of their formation, methods for their identification, and their effects in the manufacture of steel, particularly the influence on rolling and the physical properties of the steel, and their elimination during various steel-making processes.

f. Viscosity of open-hearth slags. Data are rapidly being secured on the variation of slag viscosity with composition. Viscosity influences the rate of diffusion and therefore the equilibrium between the various constituents in metal and slag.

Coal Analysis Section

a. Laboratory work on coal analyses. Samples taken in connection with the purchase of coal on specification by various Government departments, together with samples from combustion research, testing of fuels, investigation of mine explosions, classification of coals or coal-fields, etc., are analyzed by this section.

b. Development of methods and equipment. Part of the duty of this section lies in keeping its work at the highest pitch of accuracy by improvement in methods or materials.

Physical Section

Physical Laboratory

a. Accuracy of manometry of explosions. There are several different instruments for measuring the rapidly changing pressures of explosions produced by gas and dust, such as the B.C.D., the Bureau of Mines, the Crosby Gauge, and the Piezo-electric manometers. Comparative measurements with these different instruments should give standards with which to view results by different methods.

b. Relative ignitability and pressure developed in the flammation of low-temperature coke as compared to coal. Powdered coal has become a fuel of importance. In order to obtain data regarding the combustibility of powdered low-temperature coke, looking toward its use for a similar purpose, the present study was undertaken.

c. Routine calibration. The accurate instruments, such as pyrometers, thermometers, gauges, electrical measuring devices, etc., used by the various investigators in the Bureau of Mines need occasional calibration. The physical laboratory takes charge of this work.

Cryogenic Laboratory

a. Vapor-pressure composition relations for methane-ethane mixtures.

b. Vapor-pressure composition relations for methane-nitrogen mixtures. In the majority of natural gases from which helium is isolated in large-scale production, methane and nitrogen are the constituents present in the largest relative proportions. The method employed for the isolation of helium involves liquefaction of the constituents of the helium-bearing gas, at high pressures and low temperatures, except the helium which remains as gas and is pumped off as such. It is, therefore, essential for the design of efficient helium production processes to develop as many research data as possible concerning the physical properties of coexisting liquid and vapor phases of methane and nitrogen, and also methane and ethane (since the latter hydrocarbon is also present in the natural gas, often in considerable quantity) under the above indicated conditions of pressure and temperature, with special reference, in these two problems, to compositions, vapor pressures, and specific volumes of the methane-ethane and methane-nitrogen systems.

c. Specific heat of liquid ethane. Since ethane forms one of the constituents of natural helium-bearing gases, it is essential for the efficient production of helium from such gases, through liquefaction methods, to develop data with regard to ethane in the liquid state. Specific heat of liquid ethane is one of the properties of importance in this connection.

d. Removal of carbon dioxide from natural gas by refrigerating organic solvents. Helium-bearing natural gases contain more or less carbon dioxide which must be removed before the application of the process for separating helium, i.e., by means of liquefaction. Carbon dioxide is removed, in standard practice, with caustic soda. The feasibility of accomplishing the removal with possibly greater efficiency by solution or absorption of this gas in certain selected appropriate liquids at low temperatures is the subject of this problem. The design of a carbon dioxide removal unit along these lines was tentatively worked out some time ago, and trials in a laboratory scale plant were begun; the problem has, however, since then been in abeyance.

e. Search for neon in natural gas. Natural helium-bearing gases have been examined for possible neon content. Since it is impracticable to separate neon from helium on a large scale, the isolation of helium from a natural gas containing any considerable quantities of neon would result in obtaining helium contaminated to that extent with an element of practically five times its own weight, or about 7/10 the weight of air, and such helium would, therefore, not be serviceable for practical aviation purposes.

f. Heat transfer at low temperatures. Helium production from natural gas by means of liquefaction processes necessarily involves the subject of the transfer of heat from one fluid to another at low temperatures through metal walls; and the determination of the physical factors involved in such transfer is necessary for the efficient operation of such processes.

Experimental Mine Section

a. Efficacy of devices for arresting an explosion after it has traveled some distance. The value and limitations of various rock-dust barriers limiting an explosion are being tested. At the same time, a standard schedule of tests for such work is being developed.

b. Behavior of different coal dusts as regards propagation of flame. Coal dusts from typical mines in various districts are tested for ease of explosibility in air alone and in air with small percentages of natural gas to determine the explosion hazard of the mine in question. Chemical analyses of the dusts are also made and correlations between composition and explosibility are attempted.

c. Recirculation of air by auxiliary fans. An auxiliary fan under certain conditions will retake air from that which it has already sent to the working face. If firedamp is liberated at the face an explosive mixture may be accumulated. The conditions under which this may occur are being determined. The first phase has been completed and is being written up.

Electrical Section

a. Routine tests and approval of apparatus. One of the Bureau's closest contacts with industry is the work performed in connection with the investigating of various types of electrical mining equipment to determine its safety when used in mines which are gassy or may become so. Equipment tested includes small apparatus like lamps and shot-firing equipment and large equipment like coal-cutting machines, loading machines and locomotives. The industry voluntarily submits this equipment for inspection, test and approval and many operators refuse to use anything else.

b. Ignition of methane by heated surfaces. What causes some of those mysterious mine explosions? Is it the overheated mining machine bit? Is it the friction spark from a sulphur ball? Is it rock sliding down an iron chute? Is it rock grinding against rock? The Bureau hopes to answer some of these questions from the knowledge gained by research on the ignition of methane by heated surfaces.

c. Adequacy of flame safety lamps for gasoline vapors. For over a hundred years the flame safety lamp has been a recognized means of detecting gas in mines. During the last three or four years the question of the suitability of flame lamps for use in detecting gasoline vapors has come to the front. The inspection of large oil tanks and places where gasoline may collect is a very important matter. The oil industry is, therefore, very much interested in the investigation that the Bureau has undertaken to determine the safety of flame-safety lamps for this class of service.

Mining Research Section

a. Comparative efficiency of storage battery and trolley mine power. The conditions under which storage battery power can favorably compete with other electrical power for coal mines, not only for haulage and gathering locomotives, but also for mining machines, pumps, etc., are being studied. Use of storage battery power would materially reduce the explosion and shock hazard incident to exposed wires.

b. Coal mine ventilation factors. The various factors influencing the ventilation of coal mines have been worked out and are being prepared for publication.

c. Operation of mine fans. The performance of various types of fans, in various arrangements, has been studied.

Falls of Roof and Coal Section

a. Falls of roof and coal. More accidents in coal mines are caused by falls of roof and coal than by any other single cause. Studies of the circumstances under which accidents occur from falling of material from roof or sides with a view to determining methods and practices which will give promise of prevention of accidents from these causes are being actively pursued.

RARE AND PRECIOUS METALS EXPERIMENT STATION, RENO, NEVADA

a. Precious metal loss in present milling practice. Various minerals bearing small amounts of precious metals are lost in tailings under present method of treatment. The Reno Station is locating such losses and developing methods for the elimination of the waste.

b. Cyanide recovery of precious metals associated with minor copper values. The extension of cyanide recovery of precious metals to ores containing copper values under present smelting practice is being considered. The action of each copper mineral in cyanide recovery is being studied separately to secure the facts regarding their behavior during such treatment.

c. Metallurgy of chromium. The Reno Experiment Station is studying the metallurgy of chromium and developing methods of treatment applicable to domestic ores. This is especially important at this time, since we are using so much corrosion-resistant steel.

d. Recovery of radium now wasted. An improved process for the recovery of radium from low grade carnotite ores which are now being mined and milled for their vanadium content only is being devised. This by-product radium is now discarded in the tailings.

e. Centrifugal concentration. Many highly oxidized ores containing base and rare metals do not respond to the usual concentration methods. This is particularly true of the slime portion. The possibility of centrifugally concentrating these ores is being studied with favorable results to date.

f. Hydrometallurgy of manganese. The work on the utilization of domestic manganese at the Minneapolis Experiment Station is pyrometallurgical. The Reno Experiment Station is improving and developing hydrometallurgical processes for the treatment of domestic low grade ores to obtain a marketable grade at a price that will insure successful competition with the present imported supply.

g. Oil bleaching clays. Certain clays are extensively used by the oil industry for bleaching their product. At the present time there seem to be no specifications of value to producers, users, and the public in general. It is hoped in the course of this study to develop them.

h. Identification of rare and non-metallic minerals. To satisfy the demand for reliable identification of ore minerals, particularly of the rare and precious metals, the Reno Experiment Station examines approximately 50 to 75 samples each month.

MISSISSIPPI VALLEY EXPERIMENT STATION, ROLLA, MISSOURI

a. Concentration of fluorspar ores in the Illinois-Kentucky district. Most of the fluorspar ores in this district carry large amounts of impurities, while the demand is for material assaying 85 to 99% spar. The best methods and

equipment for the concentration of the fluorspar are being studied. Already methods have been developed to produce a 97% spar and the end of the improvement has not been reached.

b. Improvements in the milling of Southeast Missouri lead ores. While the milling practice of this district is at present good, it is forced by a progressively leaner mill feed to look for improvements which will permit successful operation. The reduction of the amount of lead in the tailings has been accomplished. The development of zinc ores in some of the mines and copper ores in others will be a factor compensating to some degree the decreased lead when a process is successfully worked out for their recovery.

c. Improvement of milling practice in the Tri-State Zinc district. The zinc ores of this district are yearly becoming leaner and more complex. Zinc resources will be conserved and the life of the community prolonged if methods can be developed under which this lean ore can be successfully worked. First results have led to a remodelling of the mills of the district to conform to Bureau of Mines suggestions.

d. Gravity concentration of oxidized zinc ores occurring at Gramby, Missouri. This district is an old time mining camp which has been abandoned because the ore could not be profitably milled. Recently an effort has been made to reopen some of the mines in this locality. The Bureau is attempting to develop successfully concentration methods for the oxidized zinc occurring there.

e. Means of making a segregate preparatory to chemical analysis of the sulphide minerals in a low grade domestic ore-pulp containing lead, zinc and copper. Present methods of assaying tailings containing less than 0.1% lead are unsatisfactory. An effort is being made to obtain a segregate of the sulphides so that the chemist's present error of 0.05% will be divided by the ratio of the segregate to the entire pulp. Since much material less than 0.1% lead is handled, the subject is important.

INTERMOUNTAIN EXPERIMENT STATION, SALT LAKE CITY, UTAH

a. Microscopic and determinative work. In connection with most of the problems at Salt Lake City, Tucson, etc., it is necessary to know not only the chemical, but also the mineralogical composition of the ores, concentrates, etc. being handled. Information regarding the physical condition of materials and the interrelation of minerals in a sample, often highly essential data, can only be obtained by this method.

b. Lead-zinc sulphide separation by combined roasting and flotation. Treatment by which the specific gravity or physical condition of certain minerals will be so changed that the lead and zinc can be separated by flotation or concentration is being developed.

c. Development of a method for measuring work done in crushing and grinding. Since crushing and grinding are so fundamental to ore dressing, a knowledge of the amount of work expended is of fundamental value. There is at present no method for doing this.

d. Treatment of lead carbonate ores. Methods to render oxidized and carbonate ores of lead and zinc amenable to concentration by heat treatment are being devised.

e. Flotation fundamentals. Flotation is one of the important metallurgical processes today. Data regarding the effect of varying degrees of acidity and alkalinity, presence of soluble salts, different gangue minerals, etc., are of fundamental importance and are therefore being determined.

f. Flotation of sulphides of copper and their separation from the sulphides of iron. Data are being obtained regarding the relative flotability of various copper minerals and their action with various flotation reagents. From this, proper methods of separating these several minerals from pyrite can be devised.

g. Flotation of oxidized copper minerals. The effect of various flotation reagents on the floatability of the carbonate, oxide and silicate copper minerals is being studied. These data will be used in recovering such minerals as they occur associated with low-grade copper ores.

h. Effect of finely disseminated solids (slime) on the differential separation of lead, zinc and iron sulphides. The Bureau is determining whether or not the presence of slime has any marked effect on the floatability of sulphide minerals.

i. Effect of grain size on differential flotation. Data on the effect of floatability of the amount of surface exposed per mineral grain are being secured. These results will show the difference in floatability of minerals of large grain size as compared with the same mineral in finely divided form and give data regarding proper grinding practice for flotation.

j. Study of the roasting of zinc ores as a preparation for their hydrometallurgical treatment to secure maximum solubility of zinc. A study is being made of the variables entering into the roasting process to determine under what conditions a maximum solubility of zinc can be secured.

k. Brine-ferric chloride leaching of lead-zinc tailings for recovering lead and silver. This method offers a possibility for reclaiming these metals which are now wasted in tailings.

l. A study of the forms in which lead is now being lost in smelter slags. Any steps to reduce loss of lead in slag must be preceded by a knowledge of how it is lost. This is such a forerunner of conservation.

m. <u>The manufacture of cheap calcium chloride and refrigeration to avoid losses of lead in brine leaching of lead ores</u>. Another possibility of recovering lead now lost.

n. <u>A study of the effect of certain factors on rod and ball mill crushing</u>. Data are being secured on the effect of the rate of speed, thickness of pulp, and ball load in ball and rod mill crushing.

NORTHWEST EXPERIMENT STATION, SEATTLE, WASHINGTON

a. <u>Study of the washability of fine sizes of coal on tables</u>. Fundamental studies are being carried out on the tabling of coal. The relation of the specific gravity and the size of the particle to the distribution of coal and impurities on the table has been studied. Data have also been secured on the rang of sizes which can be satisfactorily treated in one operation, the method of handling slime, securing a satisfactory separation throughout the middle portion of the table, etc. This has led to greatly increased recovery of coal in washing operations.

b. <u>Field investigations of coal washing methods</u>. Many methods of coal washing are now in use. The collection of data on their performance in commercial operating plants and the particular sphere of usefulness of each enable the Bureau engineers to assist operating companies in securing the maximum efficiency in washing their particular coal.

c. <u>Distribution of particles of various shapes and sizes on coal washing tables</u>. This subject is being studied for both sized and unsized feed in order to obtain a knowledge of the mechanism of tabling coal which will lead to improved equipment and practice.

d. <u>Stratification of particles on coal washing tables and its relation to the separation according to size, shape and specific gravity</u>. Data on the effect on table stratification of depth of bed, stroke and speed, successive stratifications of the same material, particle travel, type of feed (size, etc.,) friction of deck covering and riffles, etc., are being obtained. An understanding of these fundamentals will lead to improved washing practice.

e. <u>Study of briquetting in the Pacific Northwest</u>. Many subbituminous coals common in the northwest have no market. It is hoped to develop a demand for them by briquetting. The effect of various binders must be carefully studied.

f. <u>Measurement of the agglutinating value of coal</u>. A standard method of determining the agglutinating value of coals is being developed, in order to determine by laboratory experiment the tendency of a coal to form coke.

g. <u>Efficiency of heating kilns</u>. The efficiencies of various types of fuels, methods of firing, etc., for different types of kilns and products is being obtained in order to secure maximum efficiency in the work.

h. Dewatering of clay suspensions by use of the spray separator. The washing of clay for purification purposes leaves a slime which must be dried. The possibilities of the spray evaporator are being investigated.

i. Improved methods for preparing ochers and similar mineral pigments of the Pacific Northwest. There is much opportunity for bettering the methods used in the preparation and purification of ochers.

SOUTHWEST EXPERIMENT STATION, TUCSON, ARIZONA

a. Reaction between magnetite and ferrous sulphide. The formation of magnetite in the copper converter during smelting is one of the most costly problems with which the operator is faced as it causes loss of valuable metals in the slag and of time in operation. A knowledge of the products formed in the above reaction and its rate under different conditions is fundamental data necessary before a solution can be reached.

b. The reaction between ferrous sulphide and sulphur dioxide. It has been proposed that SO_2 be used in place of air in the copper converter. This little understood reaction needs study in connection with devising proper equipment and processes.

c. The role of capillarity in leaching coarse cupriferous material. The action of capillarity determines the speed at which leach liquors enter the pieces of ore, and hence is an important factor in the rate of the leaching process. Conditions for maximum efficiency are being determined.

d. Diffusion as a factor in copper leaching. Equally as important as capillarity, is the effect of the diffusion rate of the enriched solution out of the ore lumps. The limitations placed on the process by this factor are being studied.

e. Oxidation and reduction of iron solutions in heap leaching. The rates of oxidation of the common sulphide minerals involved in leaching and their effect on the power of the solution to dissolve various copper minerals is being studied.

f. Leaching of agglomerated finely divided material. There are hundreds of millions of tons of finely divided copper concentrator tailings in the southwest that cannot be leached in place because the heaps are impermeable to the passage of solutions. Preliminary tests indicate the possibility of agglomerating such material cheaply, after which leaching methods may be applied.

g. Chemical methods of mineralogical analysis of copper ores and products. To increase efficiency in the treatment of copper ores a knowledge of their mineral constituents is important. The best methods now in use for determining this are being tabulated and studied. New methods will be developed if necessary.

h. Drilling and blasting drift rounds. The best form of drift round to be drilled, the best explosive to be used, and the best methods of loading the holes under different conditions are being determined.

Moscow Field Office

In addition to the above, the following work is carried out in a field office at Moscow, Idaho:

a. Effect of sieve motion on screening efficiency. A careful study is being made of the effect of different motions on the sieve analysis of pulverized material. Considerable differences have been found between several common methods.

b. Relation of table feed preparation to table concentration. Data are being secured on the effect on table concentration efficiency of the preparation of the feed. From these figures the conditions best adapted to table concentration will be evolved.

c. Experimental study of efficiency of closed circuit classifiers. There is at present no method for determining absolute efficiency of closed circuit classifiers. Such a method is being devised. As soon as its worth has been proved figures will be obtained showing the efficiency of classifiers now in use.

d. Ore-dressing problems of the Coeur d'Alene mining district. The losses in present ore dressing practice in this district are being located and remedial measures devised.

PETROLEUM EXPERIMENT STATION, BARTLESVILLE, OKLA.

a. Investigation of Methods of Handling Producing Wells.
b. Investigation of Mud Fluid for Oil and Gas Well Use.
c. Separation of Wax from Lubricating Wax Distillates.
d. Study of Crude Petroleum.
e. Shooting of Oil Wells.
f. Methods of Increasing the Recovery of Oil.
g. Investigation of Sulphur Compounds in Crude Oil.
h. Investigation of the Use of Gas for Lifting Oil.
i. Study of the Flow of Natural Gas Through Pipe Lines.
j. Study of Oklahoma Asphalt.
k. Study of Disposal of Oil Field Waters.
l. Study of Evaporation Losses of Petroleum and Gasoline.
m. Chemical Treatment of Light Petroleum Distillates.
n. Safety Work.

Dallas, Texas, Field Office

a. Engineering Reports on Producing Fields.

Laramie, Wyoming, Field Office

a. The Deposition of Paraffin in Oil Wells - The Cause, Effect, and Measures Used to Overcome the Resulting Difficulties.
b. Laboratory Study of Physical Characteristics of Paraffins and Waxes.
c. Study of Methods for Producing Flowing Wells in the Rocky Mountain Region.

San Francisco, California, Field Office

a. Salvages in the Oil Industry.
b. Engine Tests on Lubricating Oils.
c. Methods of Producing Oil Wells in California.
d. Bibliography of Petroleum and Allied Substances.
e. Safety in the Natural Gas Gasoline Industry.
f. Thermal Decomposition of Oil-Shale Kerogen.

Boulder and Rifle, Colorado, Field Offices

a. Investigations of Experimental Retorts and Development.
b. Refining Study and Analytical Distillation of Shale-Oil.
c. Assay Retort Studies.
d. Study of Nitrogen Compounds in Oil-Shale and Shale-Oil.
e. Extraction and Analysis of Kerogen.
f. Weathering Tests on Oil-Shales.
g. Effect of Inert Gases on Production of Oil from Oil-Shale.
h. Experimental Refining of Shale-Oil.

PACIFIC EXPERIMENT STATION, BERKELEY, CALIFORNIA

a.. Reduction of Metal Oxides.
b. Reduction of Cuprous Oxides.
c. Specific Heats of Oxides and Sulphides.
d. Heats of Formation of Oxides and Sulphides.

SOUTHERN EXPERIMENT STATION, BIRMINGHAM-TUSCALOOSA, ALABAMA

a. Beneficiation of Low-Grade Bauxite.
b. Beneficiation of Low-Grade Phosphate Ores.
c. Coal Washing Problems in Alabama.

NORTH CENTRAL EXPERIMENT STATION, MINNEAPOLIS, MINNESOTA

a. Separation of Manganese, Iron and Phosphorus in High-Phosphorus Spiegel.
b. Resistance Offered to Flow of Gas by Columns of Irregular Solids.
c. Transfer of Heat from a Moving Gas Stream to a Column of Irregular Solids.
d. Kinetics of Iron Ore Reduction.
e. Comparative Desulphurizing Power of Blast-Furnace Slags Containing Small Percentages of Barium Oxide.
f. Plant Observations on the Reactions in the Iron Blast-Furnace.

NONMETALLIC MINERALS EXPERIMENT STATION, NEW BRUNSWICK, N. J.

a. Production and Use of Metallurgical Limestone.
b. Occurrence, Mining and Milling of Mica.
c. Application of the Wire Saw in Slate Quarrying.
d. Digest of Literature on Stassfurt and Alsatian Potash.
e. The Concentration and Treatment of Potash Ores.
f. A Field Study of the Utilization of Greensand.
g. The Effect of Anhydrite in Cement Retardation.

PITTSBURGH EXPERIMENT STATION, PITTSBURGH, PA.

Coal and Coal Products Research Section

Analytical Laboratory

a. Miscellaneous Analytical Work.
b. Coal Ash Fusibility as Related to Clinker Formation.

Microscopical Laboratory

a. Microscopic Studies of Coal.
b. Chemistry of Decay in Relation to Peat and Coal Formation.
c. Relation Between Composition and Oxidizability of Coal.

Coal Carbonization Laboratory

a. Spontaneous Combustion of Coal.
b. Determination of Reactivity of Coke in Air, Carbon-Dioxide and Water Vapor at Various Temperatures.
c. Oxidation of Sub-Bituminous Coal at Low Temperatures.
d. Survey of Methods for Determining Gas and Coke Making Properties of Coals.

Organic Chemistry Laboratory

a. Constitution of Low Temperature Tar.

Physical Chemistry Laboratory

a. Production of Methanol.

Health Laboratory Section

a. Miscellaneous Gas Analysis.
b. Miscellaneous Pathological Studies.
c. Routine Tests of Gas Masks and Dust Respirators.
d. Physiological Effect of Various Dusts on Animals.
e. Experimental Effect of Oxygen Upon Animals.
f. Disposal of Waste Waters from Mines.
g. Sealing Abandoned Mines and Determining the Cause of Alkalinity in Others.
h. Pathology of Carbon Monoxide Poisoning.
i. Relative Toxicity of Methyl Chloride, Ethyl Chloride, Methyl Bromide and Ethyl Bromide.
j. Temperature and Humidity Investigation.
k. Carbon Monoxide Recorder.
l. Occluded Gases in Coal as Affecting Inflammability of Its Dust.
m. Warning Agents for Manufactured Gas.
n. Sulfur Dioxide in Air.
o. Catalysts for Automobile Exhaust.

Explosive Section

a. Tests of Explosives to Determine Their Permissibility for Use in Coal Mines.
b. Analysis of Explosives and Explosive Materials.
c. Collecting and Testing Field Samples of Permissible Explosives.
d. Factors Influencing the Nature and Quantity of Poisonous Gases Liberated by Explosives Under Mining Conditions.
e. Determination of Limit Charge Curves for Permissible Explosives in Varying Gas-Air Mixtures.
f. Investigation of Explosions Due to Explosives.
g. Photographic Study of the Process of Ignition of Gas-Air Mixtures by Explosives.
h. Investigation of New Explosives and of New Components for Explosive Mixtures.

i. Effect of Carbon Dioxide, Nitrogen and Helium on the Limits of Inflammability of Carbon Monoxide and Hydrogen.
j. Determination of the Temperature Attained by the Products of Detonation of Explosives.
k. Effect of Confinement and Nature of Stemming and Tamping on the Charge Limits of Explosives.
l. Velocity of Detonation Across a Gas-Gap Between Two Cartridges of Explosives.
m. Metal Mine Explosives and Blasting Methods.
n. Development of Analytical Testing Methods.
o. Relation Between Oxygen Balance and Explosive Properties of Eight Samples of Forty Per Cent Gelatin Dynamite.

Fuel Section

a. Refractory Service Survey in Boiler Furnaces.
b. Soot Remover and Soot Prevention Compounds.
c. Heat Flow Meters for Furnace Walls.
d. Tests of Secondary Air Devices for Domestic Furnaces.
e. Coal Ash Fusibility as Related to Clinker Formation.
f. Determination of Relative Availability of Cokes for Use in Domestic Heating Furnaces.
g. Rating of Low Pressure Heating Boilers.

Metallurgical Section

a. Study of the Cause and Control of Abnormality in Case Carburized Steel.
b. Equilibrium Between Iron, Manganese and Sulphur.
c. Physical Chemistry of Steel Making.
d. Distribution of Iron Oxide Between Slag and Metal.
e. Formation and Identification of Non-Metallic Inclusions.
f. Viscosity of Open-Hearth Slags.

Coal Analysis Section

a. Laboratory Work on Coal Analyses.
b. Development of Methods and Equipment.

Physical Section

Physical Laboratory

a. Accuracy of Manometry of Explosions.
b. Relative Ignitability and Pressure Developed in the Flammation of Low-Temperature Coke as Compared to Coal.
c. Routine Calibration.

Cryogenic Laboratory

a. Vapor-Pressure Composition Relations for Methane-Ethane Mixtures.
b. Vapor-Pressure Composition Relations for Methane-Nitrogen Mixtures.
c. Specific Heat of Liquid Ethane.
d. Removal of Carbon Dioxide from Natural Gas by Refrigerating Organic Solvents.
e. Search for Neon in Natural Gas.
f. Heat Transfer at Low Temperatures.

<u>Experimental Mine Section</u>

a. Efficacy of Devices for Arresting an Explosion After it Has Traveled Some Distance.
b. Behavior of Different Coal Dusts as Regards Propagation of Flame.
c. Recirculation of Air by Auxiliary Fans.

<u>Electrical Section</u>

a. Routine Tests and Approval of Apparatus.
b. Ignition of Methane by Heated Surfaces.
c. Adequacy of Flame Safety Lamps for Gasoline Vapors.

<u>Mining Research Section</u>

a. Comparative Efficiency of Storage Battery and Trolley Mine Power.
b. Coal Mine Ventilation Factors.
c. Operation of Mine Fans.

<u>Falls of Roof and Coal Section</u>

a. Falls of Roof and Coal.

RARE AND PRECIOUS METALS EXPERIMENT STATION, RENO, NEVADA

a. Precious Metal Loss in Present Milling Practice.
b. Cyanide Recovery of Precious Metals Associated with Minor Copper Values.
c. Metallurgy of Chromium.
d. Recovery of Radium Now Wasted.
e. Centrifugal Concentration.
f. Hydrometallurgy of Manganese.
g. Oil Bleaching Clays.
h. Identification of Rare and Non-Metallic Minerals.

MISSISSIPPI VALLEY EXPERIMENT STATION, ROLLA, MO.

a. Concentration of Fluorspar Ores in the Illinois-Kentucky District.
b. Improvements in the Milling of Southeast Missouri Lead Ores.
c. Improvement of Milling Practice in the Tri-State Zinc District.
d. Gravity Concentration of Oxidized Zinc Ores Occurring at Granby, Mo.
e. Means of Making a Segregate Preparatory to Chemical Analysis of the Sulphide Minerals in a Low-Grade Domestic Ore-Pulp Containing Lead, Zinc and Copper.

INTERMOUNTAIN EXPERIMENT STATION, SALT LAKE CITY, UTAH

a. Microscopic and Determinative Work.
b. Lead-Zinc Sulphide Separation by Combined Roasting and Flotation.
c. Development of a Method for Measuring Work Done in Crushing and Grinding.
d. Treatment of Lead Carbonate Ores.
e. Flotation Fundamentals.
f. Flotation of Sulphides of Copper and Their Separation from the Sulphides of Iron.
g. Flotation of Oxidized Copper Minerals.
h. Effect of Finely Disseminated Solids (Slime) on the Differential Separation of Lead, Zinc and Iron Sulphides.
i. Effect of Grain Size on Differential Flotation.
j. Study of the Roasting of Zinc Ores as a Preparation for Their Hydrometallurgical Treatment to Secure Maximum Solubility of Zinc.
k. Brine-Ferric Chloride Leaching of Lead-Zinc Tailings for Recovering Lead and Silver.
l. A Study of the Forms in Which Lead is Now Being Lost in Smelter Slags.
m. The Manufacture of Cheap Calcium Chloride and Refrigeration to Avoid Losses of Lead in Brine Leaching of Lead Ores.
n. A Study of the Effect of Certain Factors on Rod and Ball Mill Crushing.

NORTHWEST EXPERIMENT STATION, SEATTLE, WASHINGTON

a. Study of the Washability of Fine Sizes of Coal on Tables.
b. Field Investigations of Coal Washing Methods.
c. Distribution of Particles of Various Shapes and Sizes on Coal Washing Tables.
d. Stratification of Particles on Coal Washing Tables and Its Relation to the Separation According to Size, Shape and Specific Gravity.
e. Study of Briquetting in the Pacific Northwest.
f. Measurement of the Agglutinating Value of Coal.
g. Efficiency of Heating Kilns.
h. Dewatering of Clay Suspensions by Use of the Spray Separator.
i. Improved Methods for Preparing Ochers and Similar Mineral Pigments of the Pacific Northwest.

SOUTHWEST EXPERIMENT STATION, TUCSON, ARIZONA

a. Reaction Between Magnetite and Ferrous Sulphide.
b. The Reaction Between Ferrous Sulphide and Sulphur Dioxide.
c. The Role of Capillarity in Leaching Coarse Cupriferous Material.
d. Diffusion as a Factor in Copper Leaching.
e. Oxidation and Reduction of Iron Solutions in Heap Leaching.
f. Leaching of Agglomerated Finely Divided Material.
g. Chemical Methods of Mineralogical Analysis of Copper Ores and Products.
h. Drilling and Blasting Drift Rounds.

Moscow, Idaho, Field Office

a. Effect of Sieve Motion on Screening Efficiency.
b. Relation of Table Feed Preparation to Table Concentration.
c. Experimental Study of Efficiency of Closed Circuit Classifiers.
d. Ore-dressing Problems of the Coeur d'Alene Mining District.

Information Circular, Bureau of Mines, Department of Commerce.

Circular No. 6061,
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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

SOURCES AND DISTRIBUTION OF MAJOR PETROLEUM PRODUCTS, CENTRAL UNITED STATES - 1926 1/

By

E. B. Swanson[2] and A. H. Redfield[3]

This analysis of sources and distribution of major petroleum products in central United States completes the series of regional studies pertaining to the distribution of petroleum products, inaugurated by the Bureau of Mines for the purpose of presenting certain fundamental statistics pertaining to the industry. Similar analyses relating to the Pacific and Atlantic Coast areas have been published.[4]

The twenty-six Central States, extending from the Appalachian Mountains on the east to the Rocky Mountains on the west and from the Canadian border to the Mexican border and Gulf of Mexico, comprising two-thirds of the National area and containing 52.5 per cent of the population, during 1926 accounted for 53 per cent of the total national gasoline consumption. Within the area are owned 55.3 per cent of the motor vehicles and road tractors registered in the United States. Three-fourths of the farm tractors are operated in this area.

Crude-oil production in these States amounted to 69 per cent of the national total, and refineries located within the area produced 61 per cent of the national gasoline supply. Gasoline recovery in these refineries was 46.7 per cent of the crude petroleum refined as compared with a national 1926 average of 38.5 per cent. In addition to supplying the regional needs for crude petroleum and its refined products the area supplied 84 per cent of the Atlantic Coast demand for crude petroleum and 62 per cent of the crude oil exports; 36 per cent of the Atlantic Coast gasoline consumption and 55 per cent of the gasoline exported; 46 per cent of the kerosene exported; 16 per cent of the Atlantic Coast fuel-oil demand and 26 per cent of the gas-oil and fuel-oil exports.

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2 Economic Analyst, Bureau of Mines, Washington, D. C.
3 Assistant Economic Analyst, Bureau of Mines, Washington, D. C.
4 Circular No. 6050, October, 1927, "Sources and Distribution of Major Petroleum Products, Atlantic Coast States, 1926," by E. B. Swanson.
"Statistical Summary of the California Petroleum Industry, 1926," by E. T. Knudsen and J. W. Mashaw.

GENERAL MOVEMENTS OF CRUDE PETROLEUM, CENTRAL STATES

The bulk of the crude oil produced within the area comes from the Mid-Continent group of States - Oklahoma, Kansas, Arkansas, northern Louisiana, and northern Texas. During 1926, this area distributed 422,963,000 barrels of crude petroleum, of which 148,684,000 barrels, or 35 per cent, were put through refineries located in the Mid-Continent region; 55,697,000 barrels, or 13 per cent, moved by pipe line to refineries located in the North Central States; 11,314,000 barrels, or 3 per cent, moved by pipe line to refineries in the Appalachian and Atlantic Coast areas, approximately 4,000,000 barrels being delivered to Appalachian refineries and the balance at Atlantic Coast points; 197,704,000 barrels, or 47 per cent, moved south into the Gulf Coast region, where it was either refined or shipped by tankers to Atlantic Coast or foreign ports; and 9,564,000 barrels, or 2 per cent, constitute a balance which consists of losses in handling and crude petroleum burned as an industrial fuel.

The Gulf Coast region in Texas and Louisiana produced 37,951,000 barrels of crude petroleum. Domestic crude put through refineries in the region totaled 155,765,000 barrels, with an additional 79,890,000 barrels required for Atlantic Coast and foreign shipments through Gulf Coast ports. This deficit between the amount produced locally and the amount distributed was supplied from the movement of 197,704,000 barrels into this region from the Mid-Continent area.

The Rocky Mountain area, consisting of Colorado, Montana, Utah, Wyoming, and New Mexico, distributed 37,543,000 barrels of crude petroleum, of which 29,205,000 barrels were refined within the area; 5,048,000 barrels were shipped by pipe line to refineries located in the North Central States; and 3,290,000 barrels were exported over the northern border into Canada.

The production of crude petroleum in the Appalachian region during 1926 was equal to the quantity put through the refineries, the only interregional movement being the shipment of approximately 4,000,000 barrels to Atlantic Coast refineries, which was compensated for by the receipt of an equal amount of crude petroleum from the Mid-Continent.

Crude-oil production in the region as a whole totaled 529,330,000 barrels, or 69 per cent of the national total, while the crude petroleum refined within the area amounted to 412,018,000 barrels, or 56 per cent of the total quantity put through refineries in the United States.

The following table summarizes the distribution of crude petroleum within the 26 States comprising the area designated as the Central States. Included in the production total are 5,392,000 barrels produced in eastern Ohio, which is usually classified as part of the Appalachian producing region; and in the total put through refineries are included 5,145,000 barrels refined in eastern Ohio, classified generally as part of the Appalachian refining area. These quantities are included in this regional report in order to present complete totals for the 26 States.

DOMESTIC CRUDE-PETROLEUM SUMMARY, CENTRAL STATES, 1926.

Production and Receipts:	Barrels	Per cent
Produced in Central States	529,330,000	99.98
Withdrawn from refinery storage	89,000	.02
Total available for distribution	529,419,000	100.00
Distribution:		
Put through refineries in area	412,018,000	77.83
Shipped by tankers to Atlantic Coast	78,795,000	14.88
By pipe line to Eastern States	11,314,000	2.14
Exported over northern border	8,499,000	1.61
Marketed as industrial fuel oil	8,256,000	1.56
Consumed as fuel on leases	3,816,000	.72
Exported over southern border	1,128,000	.21
Added to field storage	391,000	.07
Balance, including losses	5,202,000	.98
Total distribution	529,419,000	100.00

In addition to the domestic crude petroleum summarized above, 18,454,000 barrels of crude petroleum were imported through Gulf Coast ports from foreign countries. Of this amount 15,667,000 barrels were put through various Gulf Coast refineries and the balance consumed largely as an industrial fuel oil.

GENERAL MOVEMENTS OF GASOLINE, CENTRAL STATES, 1926

During 1926, 197,304,000 barrels of gasoline were distributed by refiners and marketers within the Central States. Of this quantity approximately two-thirds was consumed within the area and the remaining one-third was shipped either by tanker or tank-car to Atlantic Coast States or to foreign countries, with a small quantity shipped into the Pacific Coast area.

For the purposes of this study the central United States has been divided into three areas - the north central area, consisting of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin; the Rocky Mountain area, consisting of Colorado, Idaho, Montana, New Mexico, Utah, and Wyoming; and the South Central area, consisting of Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Kansas, and Texas.

The north central area accounted for 65.4 per cent of the gasoline consumption within the central United States, or approximately one-third of the national consumption. Although this group of States covers only 22.6 per cent of the United States area it contains 30.3 per cent of the population and 36.6 per cent of the

motor vehicles operated. Slightly less than one-half of its gasoline requirements were met from production of refineries located within the area; gasoline received by tank car from refineries in the South Central and Rocky Mountain areas supplied 51 per cent of the regional demand.

The South Central area required 29.5 per cent of the gasoline consumed within the central United States, but the gasoline production of refineries located within the area was slightly in excess of the entire gasoline consumption within the 26 Central States. The production of its refineries supplied, consequently, two-thirds of all the gasoline consumed within the central United States or shipped to other regions. Although the South Central States comprise 23.2 per cent of the national area and contains 19.3 per cent of the population, only 15.8 per cent of the motor vehicles were owned within the area and the consumption of gasoline was only slightly more then 15 per cent of the National demand.

The Rocky Mountain States comprise 21.2 per cent of the national area, but contain only 2.92 per cent of the population and 2.9 per cent of the motor vehicles registered. The area accounted for 2.6 per cent of the national gasoline demand and 5.1 per cent of the gasoline demand within the central United States. Of the gasoline produced within the area, 41 per cent was consumed and the balance shipped to other States, principally to those in the north central area.

GASOLINE SUMMARY - CENTRAL UNITED STATES - 1926

	Barrels	Per cent
Production and Receipts:		
Produced in north central area	43,454,000	22.02
Produced in south central area	133,866,000	67.85
Produced in Rocky Mountain area	15,324,000	7.77
Imported through Gulf coast ports	2,446,000	1.24
Withdrawn from refinery storage	1,338,000	.68
Received by rail from Pacific States	536,000	.27
Received by rail from Atlantic States ..	299,000	.15
Imported over northern border	41,000	.02
Total available for distribution	197,304,000	100.00
Distribution:		
Consumed in north central area	87,196,000	44.20
Consumed in south central area	39,404,000	19.97
Consumed in Rocky Mountain area	6,815,000	3.45
Shipped by tankers to Atlantic coast ...	33,589,000	17.02
Exported through Gulf coast ports	24,055,000	12.20
Shipped to Atlantic States by rail	1,203,000	.61
Exported over Northern border	1,522,000	.77
Shipped to Pacific States by rail	245,000	.12
Balance, including evaporative losses ..	3,275,000	1.66
Total distribution	197,304,000	100.00

Distinction may be drawn between the consumption in the North Central States lying east of the Mississippi River, with their diversified farming, varied manufacturing industries and relatively denser population, and those lying west of the river, with predominant grain-farming and stock-raising, little manufacturing and with a population only two-sevenths as closely settled as in the States east of the river. During 1926 the five States lying between the Great Lakes and the Ohio River consumed 61,076,000 barrels, or nearly two and one-half times the 26,120,000 barrels consumed in the six States lying west of the Mississippi. The per capita consumption of gasoline, however, did not differ greatly from 2.52 barrels in the eastern group to 2.31 barrels in the western group.

The following table summarizes the sources and distribution of gasoline in the eleven North Central States.

GASOLINE SUMMARY, NORTH CENTRAL STATES, 1926.*

Production and Receipts:	Barrels	Per cent
Produced at refineries within area	43,454,000	48.22
Received from south central area	37,977,000	42.14
Received from Rocky Mountain area	8,016,000	8.90
Withdrawn from refinery storage	369,000	.41
Received from Appalachian area	298,000	.33
Imported through northern border	1,000	--
Total available for distribution	90,115,000	100.00
Distribution:		
Consumed within area	87,196,000	96.76
Exported over northern border	1,514,000	1.68
Probable evaporative losses	861,000	.96
Shipped to Appalachian area	363,000	.40
Shipped to south central area	181,000	.20
Total distribution	90,115,000	100.00

* North central area includes Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin.

Refineries located in the South Central States manufactured 133,866,000 barrels of gasoline during 1926, or 44.6 per cent of the national production, while consumption in these States was limited to 39,404,000 barrels, or 15 per cent of the national total. Texas refineries produced 62,559,000 barrels; Oklahoma refineries, 31,533,000 barrels; Louisiana refineries, 19,403,000 barrels; Kansas refineries, 16,678,000 barrels; Kentucky refineries, 1,857,000 barrels and Arkansas refineries, 1,836,000 barrels.

GASOLINE SUMMARY, SOUTH CENTRAL STATES, 1926.*

Production and Receipts:	Barrels	Per cent
Produced at refineries within area	133,866,000	96.28
Imported through Gulf Coast ports	2,446,000	1.76
Received from Rocky Mountain area	1,348,000	.97
Withdrawn from refinery storage	1,193,000	.86
Received from north central area	181,000	.13
Received from Atlantic coast area	2,000	--
Total available for distribution	139,036,000	100.00
Distribution:		
Consumed within area	39,404,000	28.35
Shipped to north central area	37,977,000	27.31
Shipped by tankers to Atlantic coast	33,589,000	24.16
Exported through Gulf coast ports	23,805,000	17.12
Shipped by rail to Atlantic coast area ...	840,000	.60
Shipped by rail to Rocky Mountain area ...	709,000	.51
Shipped by rail to Pacific coast area	116,000	.08
Balance, including evaporative losses	2,596,000	1.87
Total distribution	139,036,000	100.00

* South central area includes Alabama, Arkansas, Kansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas.

Refineries located in the Rocky Mountain States marketed 16,609,000 barrels of gasoline, of which 6,815,000 barrels, or 41.03 per cent, were consumed within the area; 8,016,000 barrels, or 48.27 per cent, were shipped by tank car to States in the north-central area; 1,348,000 barrels, or 8.12 per cent, were shipped into the south-central area, a large portion of this passing directly through to Gulf Coast ports for export; with a balance consisting of minor shipments and losses.

The following table summarizes conditions of gasoline supply and demand in the Rocky Mountain States:

GASOLINE SUMMARY, ROCKY MOUNTAIN STATES, 1926.*

Production and Receipts:	Barrels	Per cent
Produced by Rocky Mountain refineries	15,324,000	92.26
Received from south central area	709,000	4.27
Received from Pacific coast area	536,000	3.23
Received from Canada	40,000	.24
Total available for distribution	16,609,000	100.00

* Rocky Mountain area includes Colorado, Idaho, Montana, New Mexico, Utah and Wyoming.

GASOLINE SUMMARY, ROCKY MOUNTAIN STATES, 1926.(Continued)

Distribution:	Barrels	Per cent
Consumed within area	6,815,000	41.03
Shipped by rail to north central area	8,016,000	48.27
Shipped by rail to south central area	1,348,000	8.12
Shipped by rail to Pacific coast area	128,000	.77
Exported to Canada	9,000	.05
Added to refinery storage	224,000	1.35
Balance, including evaporative losses	69,000	.41
Total distribution	16,609,000	100.00

GENERAL MOVEMENTS OF KEROSENE, CENTRAL STATES, 1926.

The central States, during 1926, furnished 63.2 per cent of the kerosene produced in the United States; accounted for 50.2 per cent of the National domestic demand; and supplied 45.7 per cent of the kerosene shipped to foreign countries. Approximately one-half of the kerosene produced within the Central States is consumed within the borders of the area and the remainder is shipped, principally through Gulf coast ports, to foreign and Atlantic coast ports. The following table summarizes the sources and distribution of kerosene in the Central States during 1926:

KEROSENE SUMMARY, CENTRAL STATES, 1926

Production and Receipts:	Barrels	Per cent
Produced by refineries within area	39,058,000	99.05
Received from Atlantic coast States	336,000	.85
Imported from foreign countries	38,000	.10
Total available for distribution	39,432,000	100.00
Distribution:		
Consumed within area	20,075,000	50.91
Exported through Gulf coast ports	10,216,000	25.90
Shipped by tanker to Atlantic coast	5,479,000	13.90
Added to refinery storage	1,219,000	3.09
Shipped to Atlantic coast by rail	183,000	.46
Shipped to Canada by rail	46,000	.12
Shipped to Pacific coast area by rail	12,000	.03
Balance*	2,202,000	5.59
Total distribution	39,432,000	100.00

* Balance includes stock increases at points other than refineries and some shipments and consumption not reported.

Of the 20,075,000 barrels consumed within Central States, 12,980,000 barrels, or 64.7 per cent, were consumed in the North Central States; 6,535,000 barrels, or 32.5 per cent, in the South Central States; and 560,000 barrels, or 2.8 per cent, in the Rocky Mountain area. Production in the three areas was as follows: North Central States, 5,951,000 barrels, or 15.2 per cent; South Central States, 31,001,000 barrels, or 79.4 per cent; and Rocky Mountain States, 2,106,000 barrels, or 5.4 per cent.

In order to make up the deficit of approximately 7,000,000 barrels between local production and demand, the North Central States received 5,189,000 barrels of kerosene from the south central area; 1,558,000 barrels from the Rocky Mountain States, and 332,000 barrels from the Appalachian region. The South Central States consumed only about a fifth of the kerosene manufactured by their own refineries, shipping 10,216,000 barrels to foreign countries, 5,479,000 barrels to Atlantic coast ports; 5,189,000 barrels to the North Central States, in addition to small shipments by tank car to the Pacific Coast and Rocky Mountain States. The Rocky Mountain area consumed only about one-fourth of the kerosene produced by refineries located within the area, shipping almost all of the balance to the North Central States.

The following table gives kerosene consumption figures for the States comprising the north central and south central areas. Those marked with an asterisk are estimated quantities, the remaining having been obtained from State inspection figures.

KEROSENE CONSUMPTION, 1926

State	Barrels	State	Barrels
Illinois	2,610,230*	Alabama	455,767
Indiana	1,042,260	Arkansas	390,664
Iowa	1,058,675	Kansas	910,552
Michigan	1,386,069	Kentucky	492,767*
Minnesota	941,719	Louisiana	800,951
Missouri	1,347,160	Mississippi	324,016*
Nebraska	688,554	Oklahoma	821,368
North Dakota	394,154	Tennessee	479,772
Ohio	2,200,000*	Texas	1,859,550*
South Dakota	436,115		
Wisconsin	875,025		
North Central	12,979,961	South Central	6,535,407

Whereas there is a certain uniformity between various States in the average consumption of gasoline, based on population and motor vehicle registration, the per capita consumption of kerosene fluctuates widely. The kerosene consumption in the South Central States west of the Mississippi River, 15 gallons per person, is nearly twice that of the Southern States east of the river, 8 gallons each. This

difference probably is due to the fact that the western group operates nearly four times as many farm tractors as the eastern group of Southern States. The average consumption per person in the five North Central States east of the Mississippi was 14 gallons, as compared with 18 gallons in the States west of the river. The eastern group operates approximately 15 per cent more farm tractors than the western group, which would indicate that the larger consumption west of the Mississippi was due to the use of kerosene in lighting and the operation of lighting plants.

INTERREGIONAL TANK-CAR MOVEMENTS

An analysis of tank-car shipments of petroleum products, based on reports submitted by a majority of companies, shows certain definite major movements. Rocky Mountain refineries, after supplying local needs, ship approximately one-half of their gasoline output to the North Central area, mainly to Nebraska, North Dakota and South Dakota. Refineries in the Mid-Continent area dispose of nearly two-thirds of their output by shipments to other States, principally in the north central area. Gasoline shipments from Northern Louisiana go mainly to Mississippi, while shipments from Arkansas are divided almost equally among the adjoining States. Gasoline for export or intercoastal trade is supplied mainly by the Texas and Louisiana coastal refineries, although, under favorable conditions, export gasoline also is supplied by Mid-Continent and Rocky Mountain refineries. Some gasoline from the coastal refineries moves by tank-car as far north as Illinois and Michigan.

Of the gasoline output of Oklahoma refineries, 83.9 per cent was shipped to other States, while 69.6 per cent of the gasoline output of Kansas refineries moved out of the State. The following table shows the percentage distribution of gasoline in the two States during 1926:

GASOLINE DISTRIBUTION, OKLAHOMA-KANSAS, 1926

	Oklahoma	Kansas
Consumed within State	16.1 per cent	30.4 per cent
Shipped to North Central States	60.9 " "	58.0 " "
Shipped to other South Central States.	20.1 " "	10.3 " "
Other shipments	2.9 " "	1.3 " "
	100.0	100.0

Both of these areas depend, for the bulk of their markets, upon the demand in the north central area. Local production of gasoline supplied 49 per cent of the demand in the north central area; shipments from the Oklahoma-Kansas-inland Texas group furnished 40 per cent; the Rocky Mountain area supplied 9 per cent; and other southern areas, especially Louisiana and coastal Texas, furnished 2 per cent. Stated in barrels, the north central area had a deficit of 46,000,000 barrels between local supply and demand during 1926. The Oklahoma-Kansas-inland

Texas area supplied approximately 36,000,000 barrels; the Rocky Mountain group, 8,000,000 barrels; and other areas, 2,000,000 barrels. With approximately one-half of the north central area's gasoline demand as a normal market for Mid-Continent and Rocky Mountain refineries, it is obvious that any increase in local production within the north central area greater than the increase in demand will tend to reduce the market for these outside refining areas.

Illinois, Ohio, and Minnesota, with respective gasoline demands during 1926 of 18,327,000, 16,211,000, and 12,807,000 barrels, are the three largest consumers among the Central States. Ohio refineries produced 6,660,000 barrels, leaving an unsupplied demand of 9,551,000 barrels as an obvious market for gasoline from other producing areas and each refining center except the Rocky Mountain area contributed in some degree towards meeting the deficit. The bulk of the deficit was supplied from Illinois-Indiana refineries, with other States ranging in the following sequence: Oklahoma, Kansas, Southern Louisiana, Kentucky, Arkansas, and Inland Texas. Aside from the gasoline which was shipped into Minnesota from Illinois-Indiana refineries, Oklahoma refineries during 1926 supplied approximately 2,000,000 barrels; Kansas refineries in excess of 1,000,000 barrels; with smaller amounts from Inland Texas and Rocky Mountain refineries. Oklahoma refineries supplied the majority of tank-car shipments into Indiana and Illinois, with Kansas refineries the next larger shippers. Refineries located in the Gulf Coast of Texas and Louisiana made some shipments into Indiana and Illinois.

Kerosene shipments are, in a general way, similar to the gasoline tank-car movements, although the relationships between the various States differ in accordance with the kerosene and gasoline consumption.

On the following pages will be found detailed tables showing tank-car movements in the Central States.

PER CENT OF TANK-CAR GASOLINE SHIPMENTS CONSIGNED TO VARIOUS STATES, 1926

Shipped to	From Okla.	From Kans.	From Inland Tex.	From Coastal Tex.	From Ark.	From N. La.	From Coastal La.
Alabama......	*	- -	1.39	3.06	2.81	1.22	20.20
Arkansas......	4.23	*	2.10	7.24	31.78	3.19	*
Colorado......	1.20	*	*	- -	- -	- -	- -
Florida.......	- -	- -	- -	*	*	*	2.43
Georgia.......	- -	- -	*	- -	1.02	1.09	9.03
Illinois......	11.66	5.43	3.70	5.12	8.95	1.41	*
Indiana.......	4.60	1.09	*	*	2.29	*	*
Iowa..........	6.23	11.05	*	- -	*	*	- -
Kansas........	2.15	30.44	*	*	1.07	- -	- -
Kentucky......	*	*	*	*	7.65	2.95	7.90
Louisiana.....	3.12	5.19	7.46	7.79	10.05	35.96	22.84
Michigan......	8.48	*	1.17	*	1.14	*	3.85
Minnesota.....	7.76	7.64	6.25	- -	2.95	*	- -
Mississippi...	*	*	2.08	5.95	1.04	39.82	14.84
Missouri......	8.20	12.52	2.68	1.03	1.72	*	- -
Nebraska......	1.53	9.27	*	- -	*	*	- -
New Mexico....	*	*	1.69	*	- -	- -	- -
Ohio..........	4.25	2.64	3.15	*	13.67	2.47	5.16
Oklahoma......	16.09	1.33	*	*	*	*	- -
South Dakota..	*	1.34	*	- -	*	*	- -
Tennessee.....	3.52	*	1.48	*	9.79	2.16	12.63
Texas.........	6.13	2.55	59.69	67.70	1.07	6.73	- -
Wisconsin.....	6.68	5.45	2.08	*	1.44	*	- -
Other States, Canada, and Mexico......	4.17	4.06	5.08	2.11	1.56	3.00	1.12
TOTAL.......	100.0	100.0	100.0	100.0	100.0	100.0	100.0
No. of tank cars reported..........	109,241	68,883	25,109	14,656	5,690	6,401	26,403
Per cent of State operated capacity included.	80	78	56	58	64	46	82

* Less than 1 per cent.

PER CENT OF KEROSENE TANK-CAR SHIPMENTS CONSIGNED TO VARIOUS STATES, 1926.

Shipped to	From Okla.	From Kans.	From Inland Tex.	From Coalstal Tex.	From Ark.	From N.La.	From coastal La.
Alabama.......	*	*	2.20	*	*	3.91	19.44
Arkansas......	3.08	*	3.31	6.58	52.73	8.92	*
Florida.......	- -	- -	- -	- -	- -	*	1.18
Georgia.......	*	- -	1.94	*	1.21	1.15	7.95
Illinois......	11.09	2.7	3.01	1.40	4.85	*	*
Indiana.......	4.91	*	1.36	*	1.82	*	*
Iowa..........	11.67	8.45	2.15	*	1.21	2.00	*
Kansas........	2.82	50.05	*	*	- -	- -	- -
Kentucky......	1.34	*	*	- -	6.67	2.12	17.20
Louisiana.....	4.33	2.56	2.88	6.58	13.33	37.51	21.06
Michigan......	3.37	*	*	*	1.21	1.32	*
Minnesota.....	8.69	4.40	3.51	*	6.67	*	- -
Mississippi...	*	*	3.48	1.44	1.82	11.85	17.90
Missouri......	11.53	12.85	1.91	*	3.03	*	- -
Nebraska......	2.83	8.12	*	- -	- -	*	- -
New Mexico....	*	*	1.24	*	- -	- -	- -
North Dakota..	1.10	*	*	*	- -	*	- -
Oklahoma......	15.67	- -	2.97	3.61	- -	- -	- -
South Dakota..	1.46	1.18	1.09	- -	- -	- -	- -
Tennessee.....	1.48	*	1.99	*	1.21	6.37	14.45
Texas.........	3.22	3.04	61.20	76.47	- -	21.24	*
Wisconsin.....	8.23	2.54	2.50	*	3.03	*	- -
Other States and Canada...	3.18	4.64	3.26	3.92	1.21	3.61	0.82
TOTAL.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0
No. of tank cars reported.......	19,319	8,709	6,038	2,218	165	2,354	6,173
Per cent of State operated capacity included.	80	78	56	58	64	46	82

*Less than 1 per cent.

DISTRIBUTION OF TANK-CAR SHIPMENTS, 1926
In Carloads

Shipped to	Gasoline	Kerosene	Gas oil	Fuel oil	Total
FROM KANSAS REFINERIES *					
Alabama........	- -	5	- -	- -	5
Arizona........	7	- -	1	- -	8
Arkansas.......	90	3	- -	49	142
Colorado.......	575	53	13	15	656
Connecticut....	- -	- -	1	- -	1
Idaho..........	7	- -	- -	- -	7
Illinois.......	3,741	189	897	1,394	6,221
Indiana........	751	85	135	210	1,181
Iowa...........	7,608	736	927	241	9,512
Kansas.........	20,969	4,359	1,650	9,910	36,888
Kentucky.......	116	11	- -	- -	127
Louisiana......	3,577	223	62	1	3,863
Michigan.......	665	29	22	34	750
Minnesota......	5,296	383	227	65	5,971
Mississippi....	4	9	60	- -	73
Missouri.......	8,623	1,119	623	5,280	15,645
Montana........	112	- -	- -	- -	112
Nebraska.......	6,383	707	232	202	7,524
New Mexico.....	97	21	- -	- -	118
New York.......	8	- -	- -	- -	8
North Dakota...	370	22	2	- -	394
Ohio...........	1,818	50	- -	14	1,882
Oklahoma.......	919	83	141	175	1,318
South Dakota...	920	103	211	9	1,243
Tennessee......	618	31	186	29	864
Texas..........	1,756	265	2	2	2,025
West Virginia..	2	- -	- -	- -	2
Wisconsin......	3,753	221	284	355	4,613
Wyoming........	60	- -	- -	- -	60
Canada.........	38	2	- -	- -	40
TOTAL....	68,883	8,709	5,676	17,985	101,253

* Compiled from reports submitted by companies whose refining capacities comprised 78 per cent of the total operated capacity during 1926.

DISTRIBUTION OF TANK-CAR SHIPMENTS, 1926 (Cont'd.)
In Carloads

Shipped to	Gasoline	Kerosene	Gas oil	Fuel oil	Total
FROM OKLAHOMA REFINERIES *					
Alabama............	81	18	1	1	101
Arizona............	489	40	- -	- -	529
Arkansas...........	4,619	596	44	37	5,296
California.........	1	- -	- -	- -	1
Colorado...........	1,303	87	1	16	1,407
Georgia............	1	3	- -	- -	4
Idaho..............	- -	3	- -	- -	3
Illinois...........	12,742	2,142	1,922	5,917	22,723
Indiana............	5,032	949	1,688	1,404	9,073
Iowa...............	6,811	2,255	384	556	10,006
Kansas.............	2,353	545	238	2,911	6,047
Kentucky...........	777	258	15	431	1,481
Louisiana..........	3,403	836	2	3	4,244
Massachusetts......	31	- -	- -	- -	31
Michigan...........	9,267	651	645	706	11,269
Minnesota..........	8,480	1,678	435	376	10,969
Mississippi........	219	41	- -	- -	260
Missouri...........	8,954	2,421	525	4,347	16,247
Montana............	7	- -	- -	- -	7
Nebraska...........	1,677	547	152	182	2,558
New Mexico.........	659	102	13	25	799
New York...........	2	1	- -	- -	3
North Dakota.......	695	212	15	2	924
Ohio...............	4,643	97	39	408	5,187
Oklahoma...........	17,575	3,027	708	17,216	38,526
Pennsylvania.......	195	3	1	- -	199
South Dakota.......	973	282	118	59	1,432
Tennessee..........	3,840	286	57	239	4,422
Texas..............	6,698	623	131	258	7,710
Utah...............	2	- -	2	- -	4
Virginia...........	19	4	- -	5	28
Washington.........	1	- -	- -	- -	1
West Virginia......	92	- -	- -	2	94
Wisconsin..........	7,294	1,590	399	1,835	11,118
Wyoming............	1	1	2	- -	4
Canada.............	305	21	1	35	362
TOTAL........	109,241	19,319	7,538	36,971	173,069

* Compiled from reports submitted by companies whose refining capacities comprised 80 per cent of total operated capacity during 1926.

DISTRIBUTION OF TANK-CAR SHIPMENTS, 1926 (Cont'd.)
In Carloads

Shipped to	Gasoline	Kerosene	Gas oil	Fuel oil	Total
FROM TEXAS INLAND REFINERIES *					
Alabama...........	352	133	7	122	614
Arizona...........	38	1	- -	- -	39
Arkansas..........	528	200	8	- -	736
California........	6	3	- -	- -	9
Colorado..........	60	13	- -	- -	73
Connecticut.......	3	- -	- -	- -	3
Georgia...........	160	117	3	- -	280
Illinois..........	930	182	455	67	1,634
Indiana...........	165	82	51	3	301
Iowa..............	220	130	111	- -	461
Kansas............	27	14	1	- -	42
Kentucky..........	48	23	5	1	77
Louisiana.........	1,872	174	5	- -	2,051
Massachusetts.....	20	- -	- -	- -	20
Michigan..........	294	23	134	2	453
Minnesota.........	1,568	212	139	- -	1,919
Mississippi.......	521	210	1	- -	732
Missouri..........	672	115	50	57	894
Montana...........	1	- -	- -	- -	1
Nebraska..........	16	45	12	23	96
New Hampshire.....	1	- -	- -	- -	1
New Jersey........	1	- -	- -	- -	1
New Mexico........	423	75	5	17	520
New York..........	5	- -	- -	- -	5
North Carolina....	7	23	- -	- -	30
North Dakota......	67	32	3	- -	102
Ohio..............	793	5	50	- -	848
Oklahoma..........	80	179	35	283	577
Pennsylvania......	31	- -	- -	- -	31
Rhode Island......	4	- -	- -	- -	4
South Carolina....	4	12	- -	- -	16
South Dakota......	101	66	9	- -	176
Tennessee.........	372	119	117	1	609
Texas.............	14,988	3,695	1,091	25,181	44,955
Virginia..........	2	4	- -	- -	6
West Virginia.....	29	- -	- -	- -	29
Wisconsin.........	523	151	134	3	811
Wyoming...........	4	- -	- -	- -	4
Canada............	171	- -	- -	- -	171
Mexico............	2	- -	102	64	168
TOTAL.......	25,109	6,038	2,528	25,824	59,499

* Compiled from reports submitted by companies whose refining capacities comprised 56 per cent of total operated capacity during 1926.

DISTRIBUTION OF TANK-CAR SHIPMENTS, 1926 (Cont'd.)
In Carloads

Shipped to	Gasoline	Kerosene	Gas oil	Fuel oil	Total
FROM TEXAS TIDEWATER REFINERIES *					
Alabama..........	448	10	2	- -	460
Arizona..........	1	- -	- -	- -	1
Arkansas..........	1,061	146	- -	- -	1,207
Florida..........	1	- -	- -	- -	1
Georgia..........	- -	1	- -	- -	1
Idaho............	- -	2	- -	- -	2
Illinois..........	751	31	59	- -	841
Indiana..........	122	10	6	- -	138
Iowa.............	- -	2	26	- -	28
Kansas...........	13	3	- -	- -	16
Kentucky..........	9	- -	- -	- -	9
Louisiana.........	1,141	146	3	9	1,299
Michigan..........	17	4	78	- -	99
Minnesota.........	- -	8	45	- -	53
Mississippi.......	872	32	1	3	908
Missouri..........	151	8	- -	- -	159
Nebraska..........	- -	- -	16	- -	16
New Mexico........	18	19	- -	- -	37
New York..........	20	- -	- -	- -	20
North Carolina....	- -	2	- -	- -	2
North Dakota......	- -	1	- -	- -	1
Ohio..............	1	10	- -	- -	11
Oklahoma..........	51	80	- -	- -	131
South Carolina....	8	- -	- -	- -	8
South Dakota......	- -	- -	1	- -	1
Tennessee.........	24	1	- -	- -	25
Texas.............	9,922	1,696	665	3,277	15,560
Wisconsin.........	25	6	1	- -	32
TOTAL........	14,656	2,218	903	3,289	21,066

* Compiled from reports submitted by companies whose refining capacities comprised 58 per cent of total operated capacity during 1926.

DISTRIBUTION OF TANK-CAR SHIPMENTS, 1926 (Cont'd.)
In Carloads

Shipped to	Gasoline	Kerosene	Gas oil	Fuel oil	Total
FROM ARKANSAS REFINERIES *					
Alabama	160	1	12	188	361
Arkansas	1,808	87	202	3,953	6,050
Florida	7	- -	- -	2	9
Georgia	58	2	- -	2	62
Illinois	509	8	702	3,434	4,653
Indiana	130	3	49	504	686
Iowa	50	2	58	213	323
Kansas	61	- -	- -	98	159
Kentucky	435	11	8	51	505
Louisiana	572	22	139	2,488	3,221
Michigan	65	2	59	45	171
Minnesota	168	11	133	38	350
Mississippi	59	3	10	3	75
Missouri	98	5	47	410	560
Nebraska	5	- -	35	594	634
North Carolina	3	- -	- -	- -	3
North Dakota	8	- -	- -	- -	8
Oklahoma	5	- -	24	243	272
Ohio	778	1	4	10	793
Pennsylvania	- -	- -	- -	5	5
South Carolina	1	- -	- -	- -	1
South Dakota	4	- -	3	- -	7
Tennessee	557	2	22	542	1,123
Texas	61	- -	- -	- -	61
Virginia	3	- -	- -	- -	3
West Virginia	2	- -	- -	- -	2
Wisconsin	82	5	81	640	808
Canada	1	- -	- -	- -	1
TOTAL	5,690	165	1,588	13,463	20,906

* Compiled from reports submitted by companies whose refining capacities comprised 64 per cent of the total operated capacity during 1926.

DISTRIBUTION OF TANK-CAR SHIPMENTS, 1926 (Cont'd.)
In Carloads

Shipped to	Gasoline	Kerosene	Gas oil	Fuel oil	Total
FROM NORTHERN LOUISIANA REFINERIES *					
Alabama	78	92	100	1	271
Arkansas	204	210	76	134	624
Florida	21	7	2	- -	30
Georgia	70	27	14	1	112
Illinois	90	20	1,106	959	2,175
Indiana	43	15	187	149	394
Iowa	20	47	68	41	176
Kansas	- -	- -	- -	70	70
Kentucky	189	50	13	- -	252
Louisiana	2,302	883	930	6,995	11,110
Michigan	12	31	128	164	335
Minnesota	14	11	99	86	210
Mississippi	2,549	279	281	227	3,336
Missouri	16	5	61	62	144
Nebraska	1	2	1	32	36
North Carolina	- -	- -	4	- -	4
North Dakota	- -	6	- -	- -	6
Ohio	158	1	8	19	186
Oklahoma	2	- -	- -	144	146
Pennsylvania	3	- -	5	- -	8
South Dakota	4	- -	1	2	7
Tennessee	138	150	85	4	377
Texas	431	500	288	3,591	4,810
Virginia	18	3	- -	- -	21
Wisconsin	38	15	345	45	443
Canada	- -	- -	2	- -	2
TOTAL	6,401	2,354	3,804	12,726	25,285

* Compiled from reports submitted by companies whose refining capacities comprised 46 per cent of total operated capacity during 1926.

DISTRIBUTION OF TANK-CAR SHIPMENTS, 1926 (Cont'd.)
In Carloads

Shipped to	Gasoline	Kerosene	Gas oil	Fuel oil	Total
FROM SOUTHERN LOUISIANA REFINERIES *					
Alabama............	5,333	1,200	96	815	7,444
Arkansas...........	118	- -	10	2	130
Florida............	642	73	56	- -	771
Georgia............	2,384	491	181	83	3,139
Illinois...........	22	1	130	39	192
Indiana............	14	5	64	13	96
Iowa...............	- -	2	- -	- -	2
Kentucky...........	2,085	1,062	79	22	3,248
Louisiana..........	6,029	1,300	908	1,636	9,873
Michigan...........	1,016	15	55	520	1,606
Mississippi........	3,919	1,105	103	336	5,463
North Carolina.....	- -	- -	17	- -	17
Ohio...............	1,362	23	144	50	1,579
Pennsylvania.......	2	- -	- -	3	5
South Dakota.......	- -	- -	3	- -	3
Tennessee..........	3,335	892	101	101	4,429
Texas..............	- -	1	- -	- -	1
Virginia...........	1	3	1	- -	5
West Virginia......	29	- -	- -	- -	29
Wisconsin..........	- -	- -	8	2	10
Canada.............	112	- -	63	- -	175
TOTAL.......	26,403	6,173	2,019	3,622	38,217

* Compiled from reports submitted by companies whose refining capacities comprised 82 per cent of total operated capacity during 1926.

Information Circular, Bureau of Mines, Department of Commerce.

Circular No. 6063
March, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

MINE RESCUE ORGANIZATION IN THE COEUR d'ALENE MINING DISTRICT, IDAHO[1]

By W. J. Fene[2] and Hugh McDermott[3]

Introduction

The Coeur d'Alene mining region of Idaho, comprising a number of properties employing several thousand persons, operated with heavy tonnage for over 20 years with almost total immunity from underground fires until the mining companies felt that the fire hazard, in the underground workings at least, was negligible. The mines work both ore and country rock which are singularly free from combustible material, and spontaneous combustion involving vein or wall material is practically, if not wholly, unknown. Moreover, underground rock and water temperatures in general have been remarkably low, and even in the most poorly ventilated places with maximum heat from moving stopes or wall material or from oxidation of crushing timber the temperatures have been less than 90° and usually less than 80°. On the other hand, much heavy timbering has been necessary in several mines, and in some instances there has been considerable crushing of timber. The mines, at least in the upper workings, have gradually become dry, and there has been free use of open lights, smoking, and various kinds of electrical equipment, wiring, etc., which, unless adequately safeguarded, together with the extensive timbering, give almost ideal conditions for mine fires to start and spread.

As previously stated, there had been singular immunity from underground fires for some years, and not until after the disastrous fire in the North Butte mine, Butte, Mont., in 1917 was there any considerable amount of apprehension regarding fires in the mines of the Coeur d'Alene. However, between 1917 and 1923 there were several rather serious fires in the larger mines of the region, and the fire hazard was brought definitely to the attention of the operators of that region.

As a result of a concerted movement among the Coeur d'Alene mine operators, a mine rescue organization was perfected and a mine rescue station established under the direction of K. T. Sparks, engineer of United States Bureau of Mines mine rescue car No. 9. Mr. Sparks was later appointed director of the station, a position he still retains.

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2 - Associate mining engineer, U. S. Bureau of Mines.
3 - Foreman miner, U. S. Bureau of Mines.

The Coeur d'Alene Mine Rescue Station is maintained by the members of the Operators' Association who contribute to a general fund at the rate of 5 cents per ton of ore mined; an agent appointed by the mine operators administers this fund. By this arrangement the cost of maintaining the station is distributed according to the output of each mine.

The rescue equipment of the Coeur d'Alene district forms one of the most complete installations in the United States. No expense has been spared to make it complete, and it represents an investment of about $35,000.

Housing Facilities

After considering the facts that most of the mines to be served were located on a railroad and that the use of a truck was not feasible during the winter months, due to deep snows, it was decided that the apparatus and supplies should be housed in a railroad car, and a former Bureau of Mines rescue car was purchased for this purpose. The car was equipped to suit local conditions and has living quarters for a small crew. This rescue car, which forms the nucleus of the central mine rescue station for the district, is stationed in Wallace, near the center of the district, where a special engine is available at all times to take the car to the scene of a mine disaster.

Equipment

As most of the rescue men in the district were more familiar with the Paul oxygen breathing-apparatus than any other type and there is also available much Paul equipment in Butte which could be obtained with little lapse of time in an emergency, this apparatus was selected as standard for the district. Fourteen sets of Paul apparatus are carried on the car, with a supply of oxygen, oxygen pumps, regenerating material, gas masks, self-rescuers, life line, inhalators, gas-testing apparatus, specially designed water nozzles, and accessory fire-fighting equipment.

Rescue Stations Located at Mines

Besides the central mine rescue station at Wallace five companies have complete stations located at the mines. All of these stations are equipped with 5 to 15 sets of apparatus and an ample supply of spare parts, oxygen pumps, and regenerating material. At three of these mines four sets of apparatus are kept underground at points where they may be readily reached in case of a fire. These apparatus are placed in steel cabinets where an electric lamp is always kept burning to keep the air dry and so prevent moisture from causing the apparatus to deteriorate. There is also placed in these mines a number of self-rescuers at points where they may readily be reached. If a large mine fire occurs in the district all of the equipment at each of the mine stations, as well as the equipment from the rescue car, a total of 99 sets of apparatus, could be concentrated in one place in a very short time. The location and types of oxygen-breathing apparatus and accessories are given in the subjoined table.

Training of Rescue Men

The rescue crews are selected from the hoisting engineers, oilers, mining engineers, foreman, shift bosses, electricians, pipemen, timbermen, and miners. In selecting mine rescue men from the different works around the mine, there are always available men who can do any kind of work necessary underground during a mine fire. Also there is always kept trained a crew of surface men familiar with the underground workings, who may serve if the underground crews are trapped.

The men are trained in groups of five for a period of three months at three-week intervals, receiving 16 hours of actual training. After the first course of training is completed the men are given additional practice with the apparatus one afternoon each month for an indefinite period. About 200 men in the district are in active training at all times.

The men are released from their regular work for the training and practice periods and receive their regular compensation. Several mines pay their rescue men a bonus of 25 cents per shift over their regular scale of wages, which results in there always being a demand for places on the rescue teams. When engaged in actual fire fighting or rescue work the men are paid a bonus of $5.00 per day over their regular wages.

In conjunction with the mine rescue training a certain amount of first-aid training is also given, especial attention being paid methods of artificial respiration. During the visits of a Bureau of Mines car to the district, first-aid classes are held, and the mine rescue men are examined and recommended for Bureau of Mines certificates.

Information Circular, Bureau of Mines, Department of Commerce.

MINE RESCUE APPARATUS, COEUR D'ALENE DISTRICT

Company	Employees	Apparatus men trained	Apparatus	Oxygen pump	Apparatus underground	Caustic soda regenerators	Cans of cardoxide	All-service gas masks	Other apparatus Fleuss	Other apparatus Draeger#
Hecla Mining Co., Burke, Ida.	350	42	9 sets Paul	Fleuss power	4	300	400			3
Bunker-Hill Sullivan Co., Kellogg, Ida.	500	55	11 sets Paul	Draeger power	4	300	300	7 sets 14 canisters	5	4
Federal Mining Co., Mullan, Ida.	400	48	12 sets Paul	Draeger power Draeger hand	4	400				
Hercules Mining Co., Burke, Ida.	150	12	14 sets Paul	Draeger power Draeger hand	0	500			5	
Tamarack-Custer Mining Co., Gem, Ida.	150	35	18 sets Paul	Draeger power Draeger hand	4	700				
Coeur d'Alene Rescue Car 1.	Man in charge		12 sets Paul 5 sets $\frac{1}{2}$ hour type	Draeger power Fleuss hand		900 200 $\frac{1}{2}$ hour cans		3 sets 7 canisters	1	

#Draeger and Fleuss apparatus in good condition and can be used if needed. Page Mining Co., Osburne, Ida., and Gold Hunter Mining Co., Mullan, Ida., have no apparatus at mine but are served from Rescue Car.

Circular 6064.
April, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

ACCIDENT-PREVENTION WORK OF THE MIDWEST REFINING CO.[1]

By E. H. Denny[2]

As the result of the work of an efficient safety organization, the Midwest Refining Co. at its various operations and particularly in the Salt Creek field has been able to show a definite accident reduction. Lost-time accidents during the past year have been reduced to a small number as compared with previous years, and infection cases have been almost eliminated.

The accident-prevention work of the Midwest Refining Co. is in charge of the department of industrial relations, with a director as the administrative head; two safety men handle the work directly at Midwest, Wyo. A competent medical staff with a well-equipped hospital at Midwest is also an important factor in the prompt and proper treatment of injured persons. When an employee is injured, he is given first-aid and then taken to the hospital with minimum delay.

About 1,450 persons are employed in the 4 departments (production, gas, pipe lines, and electrical) and in the 34 districts of the Midwest Refining Co. The work at Midwest spreads over a considerable area, and new drilling operations, pipe work, and similar activities require the services of many small gangs of workers. Complete supervision of each job, whether small or large, is possible through the large number of superintendents, foremen, and gang pushers employed; thus, there are 20 superintendents, 78 foremen, and 115 gang pushers. The largest number of men under any one boss is approximately 15, and it is probable that much of the good safety record is due to this intensive supervision. These company officials, including the gang pushers, have been impressed with the idea that it is their duty to see that the men under them do not get hurt; the responsibility of instructing new employees in safety practices is placed directly upon them. Monthly meetings of the field officials, including superintendents, foremen, and gang pushers, and as far as possible the men, of each district are held with the safety engineer. Both officials and men are encouraged to bring up for discussion any practice or proposals looking to the changing of any conditions that will

1 This article is not subject to copyright. Reprinting, with customary acknowledgment to the Bureau of Mines will be welcomed.

2 District Engineer, U. S. Bureau of Mines.

promote safety, and accidents of the past month are discussed in detail. These meetings are varied by occasional social events; they have been conducted since April, 1927, and it is chiefly since their start that accidents have decreased markedly.

First-aid treatment of injured men has been found to be an important factor in lessening the severity of accidents and in almost eliminating infection. First-aid training for officials and employees was begun by U. S. Bureau of Mines Car 2 about four years ago, and 1,028 out of the 2,200 then employed by the Midwest Refining Co. in the Salt Creek field completed the Bureau of Mines first-aid course. This training was followed by the distribution of first-aid kits to the various superintendents, foremen, gang pushers, automobile drivers, and, in general, all persons in any official capacity. The contents of the first-aid kits are used as needed, and the kits are brought in to the safety inspector once a month for checking of contents and for refilling. This matter of bringing in kits for inspection is done in connection with the monthly safety meeting, and it helps to secure the attendance of the bosses. Interest in first-aid training is maintained largely through an annual first-aid contest, in which nine teams participated last November, and through first-aid practice at safety meetings. The annual visits of the Bureau of Mines instructors also aid materially in maintaining interest in the work. There are 400 first-aid kits available "on the job."

On February 21, 1928, a first-aid meet was held at Midwest, Wyo., in which 16 teams competed; over 700 persons witnessed the meet, including the vice-president and other high officials of the company as well as executives of other oil companies of Wyoming and Colorado. Several hundred people were unable to gain entrance to the hall where the contests were held.

The safety department of the Midwest Refining Co. investigates all accidents, fixes the responsibility therefor, and prepares and issues bulletins briefly describing the accidents or dangerous conditions found. These bulletins are well illustrated with photographs and are placed where they can be easily read by the men. The safety department maintains a thorough inspection of working conditions and practices to eliminate those that are unsafe. Publicity is given to accident-prevention results by flying a safety flag in each district for such portion of each month period as the district has no lost-time accidents. The number of days each flag was flown during the month is also reproduced diagrammatically in the company's monthly publication, the Midwest Review; a summary of accident-prevention results during the month is also given in the Review, with other information of interest on safety work. This publication is attractively arranged, describes the various activities of the camp, is well illustrated, and also gives much of educational interest regarding the State, the company, and individuals employed by this company.

The appended graphs prepared by the Midwest Refining Co. show on different bases the accident record of the company for the past three years. Figure 1, A, shows the number of accidents by months. The marked decline in the number of accidents in 1927 as compared with previous years is especially notable.

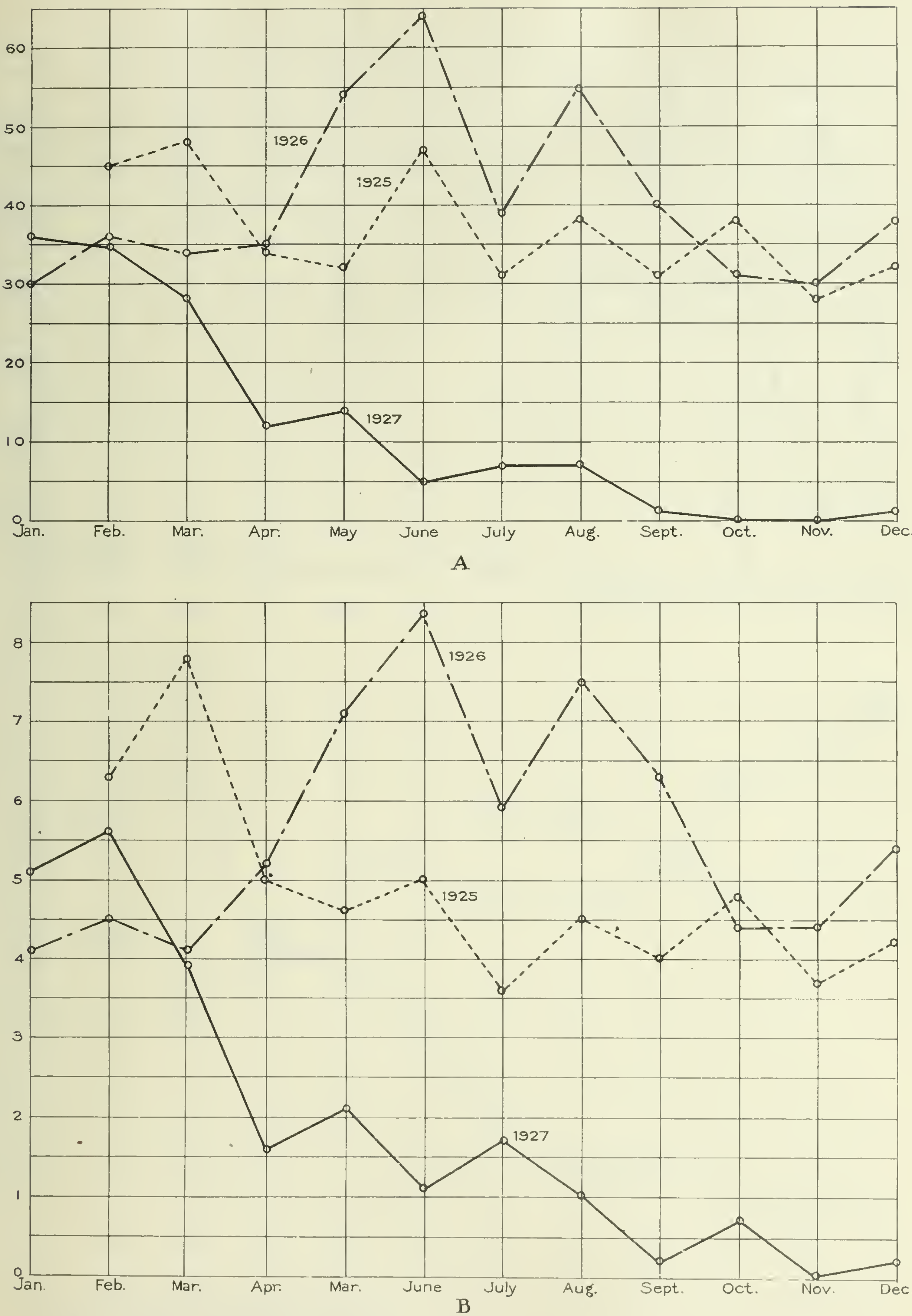
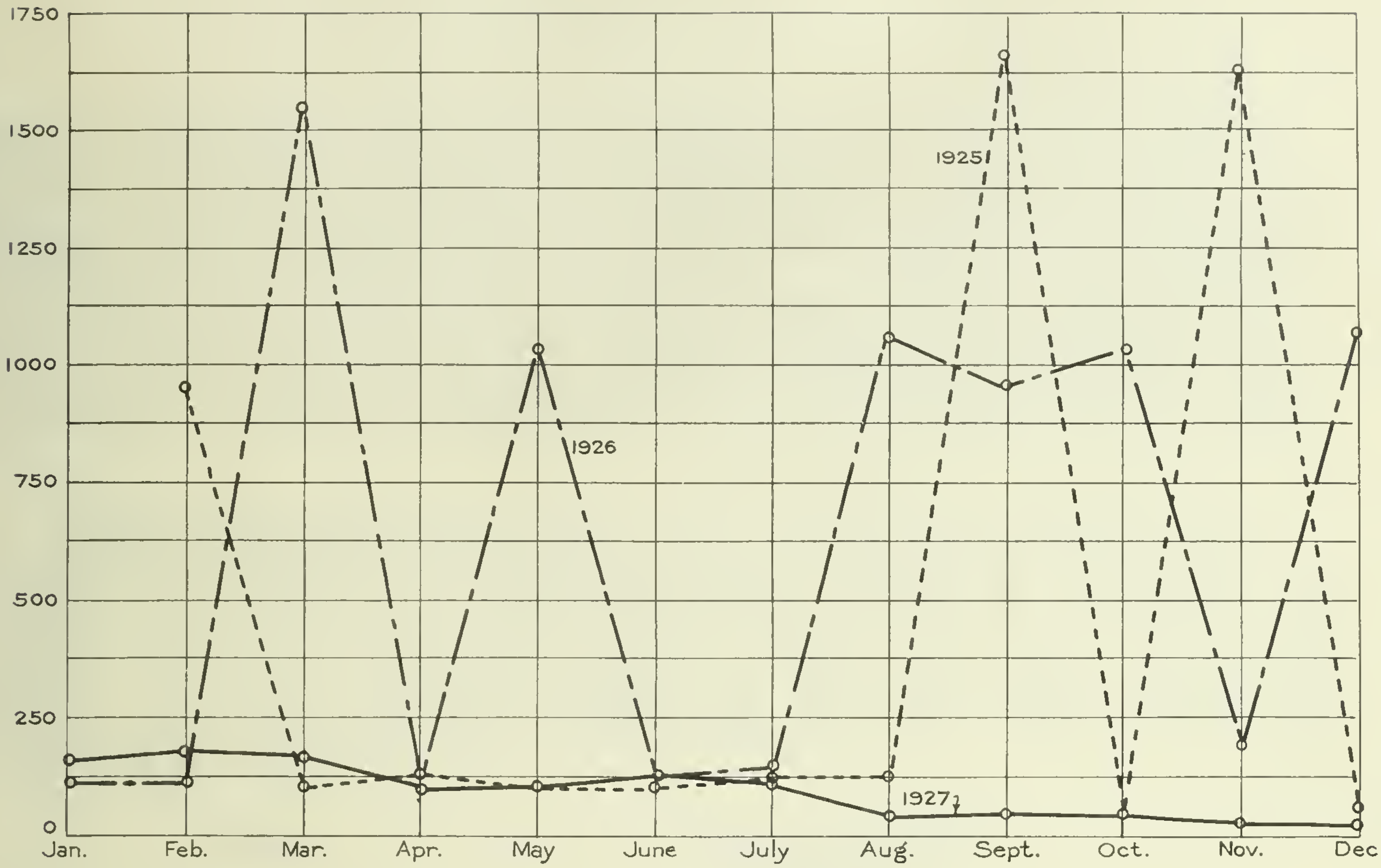
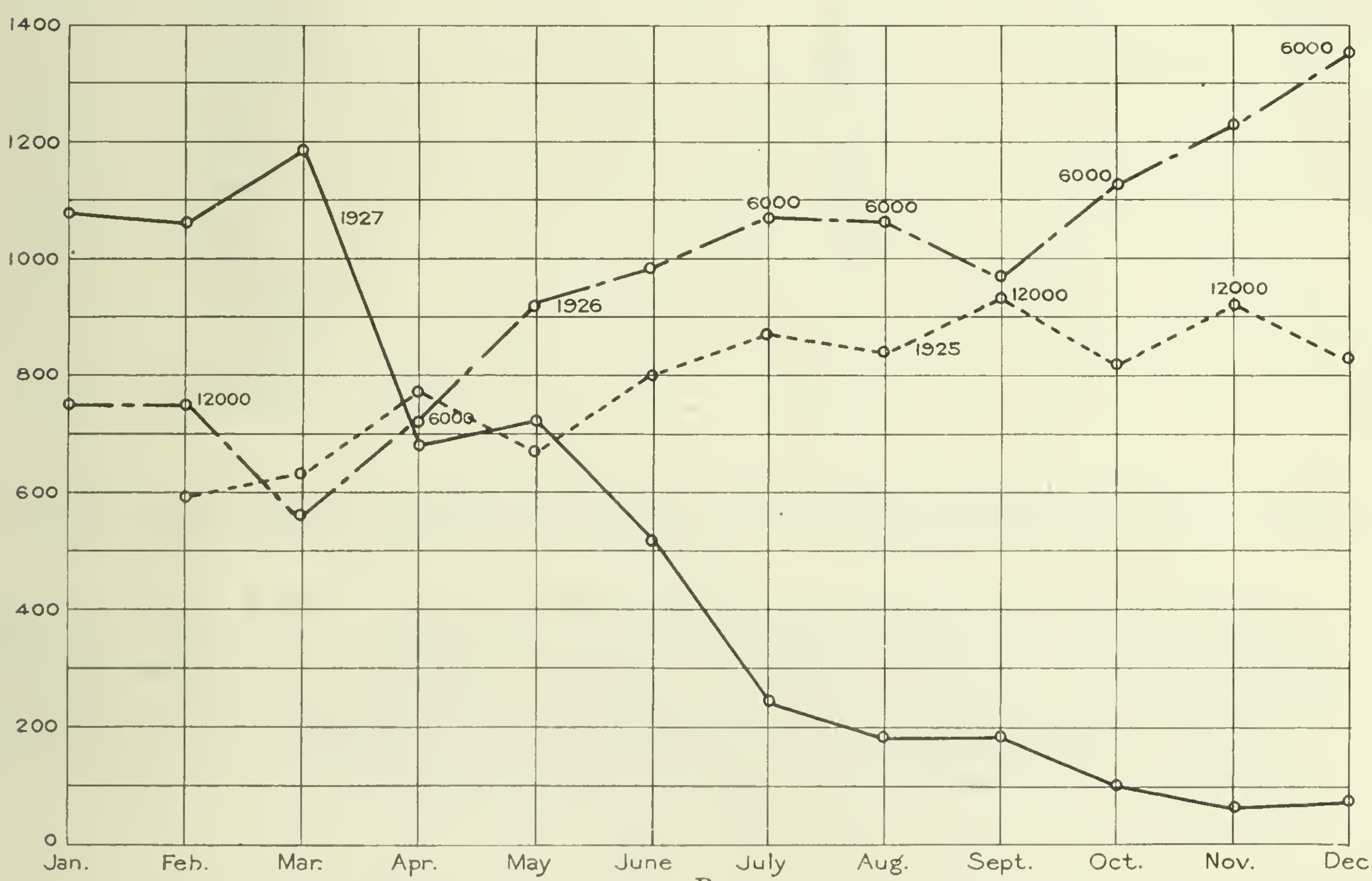


Figure 1. A, Number of accidents by months; B, frequency rate by months and years; frequency rate = number accidents per 10,000 days worked.



A



B

Figure 2. A, Severity rate by months and years; severity rate = number days lost per 10,000 days employed; B, days lost by months and years.

Figure 1, B, shows the frequency rate of accidents or the number of accidents per 10,000 days work. This also shows a marked decline for the current year. Figures 2, A, shows the severity rate of accidents or the number of days lost per 10,000 days employed. During 1927 the severity curve shows a very low severity rate. Figure 2, B, shows the number of days lost by months and years through temporary disability. The figures included at various points on the curves for 1925 and 1926 indicate also that one or more accidents involving permanent disability occurred, each death or total permanent disability being rated as 6,000 days lost time. It will be noted that none of these cases have occurred during 1927.

Accident-prevention results may also be visualized by definite figures. It is estimated roughly that accidents in 1924 cost the Midwest Refining Co. $200,000, in 1925 $150,000, in 1926 $82,000 and in 1927 $25,000. When this report was prepared, there had been two infection cases during 1927 out of 137 lost-time accidents. Some years ago infection occurred in about one-third of the lost-time accidents. A lost-time accident is charged when one or more days of working time are lost by the injured employee. The record of lost-time accidents for 1927 up to October is as follows:

Month	No. of lost-time accidents.
January	36
February	34
March	28
April	11
May	11
June	3
July	5
August	7
September	1
October	0
November	0
December	1
	137

During October and November, 1927, no lost-time accidents occurred in the Salt Creek field, and 106 days elapsed without a lost-time accident.

The labor turnover at the Midwest Refining Co. operations is estimated roughtly at 3 per cent. Over 90 per cent of the employees are Americans. By the State compensation law an employee gets $50 a month compensation for any accident in which he loses more than 7 days. A careful check is kept of all persons off duty on account of accidents to insure that they are obtaining proper attention and taking proper care of themselves and that they will return to work when fit.

To summarize, through an active safety department, a well-trained safety organization of officials and men, and complete supervision, accidents at the operations of the Midwest Refining Co. are being reduced to a minimum. Monthly safety meetings of both field officials and men at which the responsibility of field officials for accident-prevention results has been emphasized are an important factor in the results obtained. These results demonstrate that accident-prevention is definitely and readily possible in the oil-producing industry, and apparently one of the most essential factors in the prevention of accidents is intensive supervision.

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Circular No. 6066
April, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

FORM OF REPORT FOR UNDERGROUND ACCIDENTS[1]

By E. D. Gardner[2] and D. J. Parker[3]

A full knowledge of the underlying causes of accidents at mines is of great value in accident-prevention work. Close analysis of the reasons for each accident that occurs furnishes information that can be used in planning measures for the prevention of similar accidents. To get this information a complete and impartial investigation and report of the conditions that made possible the accident should be made.

The authors believe that the mine superintendent or the safety man at the mine should make this report to the general manager probably sending copies to intervening operating officials. In this way the responsible officials of a company may obtain personal knowledge of the causes of accidents at the property and are in a better position to institute the proper corrective measures; also, the interested operating officials are kept informed regarding charges made against them and may defend themselves or take measures against the recurrence of accidents.

When an injury may be the basis of a civil suit against the company, there is perhaps an unconscious tendency by those making reports to emphasize the culpability of the injured person and to minimize the fault of the company. Certainly a report by a mine official placing the blame for an injury on the company would materially assist a claimant to obtain damages, should such a report come into the hands of a trial jury.

In many States a definite compensation is set by law for injuries or time lost owing to injuries received while on duty, irrespective of responsibility for the accident, and complete and frank reports should be demanded. Before a fault can be corrected it must first be recognized, and in general companies are willing to assume their full responsibility for each accident. Certainly an accident report excusing any action or act of omission of a company official or minimizing the effect of a faulty method or practice should not be tolerated.

2 Supervising Engineer, U. S. Bureau of Mines, Tucson, Arizona.
3 Supervising Engineer, U. S. Bureau of Mines, Berkeley, California.

A man may be injured as the result of direct violation of a safety rule or because of not performing a certain duty as instructed; however, in many such instances faulty mining practices or poor equipment may be partly responsible for the accident. Moreover, discipline may be so lax that the injured person had no worry about the violation of the rule.

Accident reports that are made without sufficient study of the causes of the accident have little value other than to a certain extent for statistical purposes. The apparent reason given for an accident may be correct as far as it goes, but a close study will often bring to light contributing underlying conditions that should be corrected. An accident report to the responsible executive summarizing accidents over a definite period of time should forcibly bring to his attention all conditions that are in any way responsible for a high accident rate. Unless impartiality is followed in this, the reports are essentially worthless.

As an aid in obtaining knowledge of the underlying causes of accidents, the following tentative outline for reporting such accidents is offered. It is realized that such a detailed report involves considerable work, but it is believed by the authors that all extra effort having for its aim the prevention of accidents is more than justified. In some cases, items will be impossible to obtain and in others where there is undue difficulty in obtaining information, it should in general be omitted.

OUTLINE FOR ACCIDENT REPORT TO GENERAL MANAGER

(1) Injured man:
- (a) Name.
- (b) Age.
- (c) Nationality.
- (d) Speak English?
- (e) Does the boss speak worker's language?
- (f) Experience in mining--When, Length of time each place.
- (g) Length of employment in this mine.
- (h) How long on "job" at which injured?
- (i) Rate of pay.
- (j) Dependents--Number--Age.
- (k) Previous injuries in this mine and in other mines.

(2) Boss in immediate charge:
- (a) Experience in mining and as "boss." Age. Nationality.
- (b) How long on run and extent of run? How many times does he see his workers each shift?
- (c) Safety record. Detail as much as feasible.

(3) Injury:
- (a) Description.
- (b) First aid administered? If so, by whom administered?
- (c) Distance to nearest first-aid box. Condition of first-aid box.
- (d) Sent to hospital?
- (e) Time required to reach hospital.
- (f) Probable length of disability.
- (g) Probable cost to company.
- (h) Probable ultimate effect on victim.

(4) Accidents:
- (a) Place.
- (b) Time, including time of day, date, etc.
- (c) Time boss or bosses visited working place.
- (d) Workman engaged in what work.
- (e) Tools or equipment being used. Condition of same. Tools supplied by victim?
- (f) Was man working at regular "job?"
- (g) Description of work being done at time of accident.
- (h) Injured person's statement.
- (i) Witnesses.
- (j) Statements of witnesses (taken if possible before going home).

(5) Cause of accident:
- (a) Give safety rule intended to prevent such accidents. Is such rule posted?
- (b) Did man violate safety rule, order, or law?
- (c) Had he previously been observed violating safety rules? Give details.
- (d) Was absent-mindedness or stupidity of injured person involved in accident?
- (e) If so, how?
- (f) Had injured man received definite and specific instructions how to perform the particular job on which he was engaged?
- (g) If so, what were these instructions and when and by whom given?
- (h) Had boss been given orders to give such instructions? If so, by whom?
- (i) If not, why not?
- (j) Was mining practice at fault? Give reasons.
- (k) Would any modification of mining practice have helped prevent accident?
- (l) If so, what modification?
- (m) Was faulty or insufficient equipment involved in accident? Give details.
- (n) Would equipment better adapted to the work have prevented the accident?
- (o) If so, describe such equipment and indicate what would have been the cost of supplying such equipment.

(6) General:

(a) Have similar accidents occurred before in the mine?
(b) Proportion of similar accidents on the boss's run to those in rest of mine?
(c) What if any discipline is meted out for this accident?
(d) Did boss lose a safety bonus?
(e) How long since foreman inspected place before accident?
(f) How long since safety engineer inspected place before accident?
(g) How long since superintendent inspected place before accident?
(h) Has superintendent visited scene of accident and investigated cause?
(i) Has safety engineer visited scene of accident and investigated cause?
(j) Had safety engineer made any suggestions which if followed out would have prevented accident?
(k) What steps are being taken to prevent a recurrence of such an accident or of any accidents of similar nature?
(l) Why were such steps not taken before this accident occurred?
(m) Is expense of accident charged against tonnage or footage costs in working place?
(n) What is total cost and cost per ton or foot of all accidents in this working place during last year?
(o) What is proportion of accident cost to total costs in this working place?
(p) Boss's statement.
(q) Foreman's statement.
(r) Safety engineer's statement.
(s) Superintendent's statement.

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Circular No. 6067,
May, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

TOUCH PAPER[1]

By
D.J. Parker[2]

One of the major problems to which the U. S. Bureau of Mines has given a great deal of time and study since its organization is greater safety in blasting in coal mines, particularly with reference to gassy mines. In the study of this problem the Bureau has usually had the hearty cooperation of manufacturers, operators, and officials of State mining departments. There has been a fairly generous adoption of the use of permissible explosives in many States, together with other related recommendations by the Bureau for safer methods in blasting. Utah prohibits the use of any other explosives than permissibles in the blasting of coal. Generally the trend has been in the right direction, but there are some decided exceptions to this, and in some of the coal-mining districts in the State of Washington there is in use a somewhat unique, antiquated, and potentially hazardous practice--firing shots in gassy coal mines by the use of so-called "touch paper."

Touch paper is usually made at the mine by the lamp man, by thoroughly soaking ordinary cardboard about 1/16 inch thick in a solution of water and saltpeter in the proportion of 1 ounce of saltpeter to 1½ pints of clean water. In some instances vinegar is used with the saltpeter instead of water. The impregnated cardboard is dried, usually in an oven, and cut into strips about 1 inch wide. The cardboard, which is now touch paper, is ready for use by the shot firers. The shot firers enter the mine after the shift is out equipped with a permissible electric cap lamp, a key-locked flame safety lamp, and a supply of touch paper. Permissible explosive, cap and fuse, and incombustible stemming are used for the most part in mines that are on a closed-light basis. The coal pitches from 30 to as high as 80° in some of the mines west of the Cascade Mountains. Solid shooting prevails in these pitching beds.

The shot firers, who are qualified fire bosses in accordance with State regulations, first made a careful inspection for the presence of methane at the face to be blasted, using the low or nonluminous flame. If the place is clear of explosive gas the procedure is as follows: (1) The flame in the safety lamp is extinguished, (2) the bowl of the lamp is unscrewed from the top, (3) a strip of

1 This article is not subject to copyright. Reprinting, with customary acknowledgment to the Bureau of Mines, will be welcomed.
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touch paper about 2 inches in length is placed on the bowl of the lamp near the wick, (4) the lamp is reassembled, (5) the lamp is relighted, which enables the shot firer to ignite the touch paper, (6) the lamp is again extinguished, (7) the lamp is taken apart as before and the touch paper, which is now burning along the edge with a glow, but no flame, though with an occasional sputter due to the saltpeter, is removed, and (8) the lamp is again assembled and lighted. This procedure is repeated as often as may be necessary during the shift. The touch paper is then used to light the fuse. All shots are lighted in rapid succession, reliance being placed on the varying lengths of fuse to insure their going in proper sequence. This of itself is a decidedly unsafe practice inasmuch as all shots except the initial one are dependent shots. In addition to this other definite hazards exist, due to this system of blasting. The key-locked flame safety lamp is not the least of these and use (or possibly it is better to say misuse) of the key-locked flame safety lamp has resulted in considerable loss of life and property. It should be discarded for the permissible magnetic-locked lamp. The glowing touch paper, to all intents and purposes, constitutes an open light and again there is the possibility, even a very definite danger, of ignition of gas from the burning fuse.

Electric blasting employing delay-action detonators would be much less hazardous than the present system and could be used to advantage, no doubt, were it not for the fact that it would still involve the dependent shot feature, and there might be ignition of gas or dust from those shots which immediately follow others. The safer method, and the one the U. S. Bureau of Mines urgently recommends, is the firing of one shot at a time electrically, with a permissible single-shot blasting unit, using a detonator of suitable strength (not less than a No. 6). The Bureau of Mines has approved for permissibility eight single-shot blasting units.

Under this system it would be necessary, of course, for the shot firer to climb to the face in the case of steep pitches to attach the firing line to each succeeding shot. This reason has been advanced in justification of the present system as against electric blasting. It is believed, however, that the safety features involved in single-shot electric blasting will far outweigh any trouble or additional expense incurred incident to its adoption.

Undoubtedly the safest blasting system to use in these mines is that used widely in the coal mines of Utah, where all shots are fired electrically, from the surface when every one, including the shot firers, is out of the mine.

Similarly, in these same districts the practice of lighting shots with round braided lamp wicking (lamp cotton) prevails in certain closed-light mines. Prior to entering the mine the shot firer lights one end of a roll of wicking which burns with a dull glow. Whenever the fire tends to become extinguished the wicking is whirled rapidly until the desired degree of combustion is restored. When the face is reached the same procedure is followed as with touch paper. What has been said with reference to existing hazards incident to the use of touch paper is equally applicable to the practice of using lamp wicking for firing shots.

There is no doubt of the very definite danger in using either the touch paper method or glowing cotton wick with fuse in blasting coal. Safety demands that these antiquated methods be abandoned for the more modern and far safer method of blasting electrically.

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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

DEVELOPMENT AND SAFETY OF THE STORAGE - BATTERY LOCOMOTIVE [1]

By L. C. Ilsley[2]

The underlying principle of the storage battery was discovered within the memory of many still living, hence storage-battery locomotives, which were made possible by this discovery, represent a still more recent development. The Journal of the Franklin Institute for December, 1883, gives an account of the building of an electrical omnibus by The Electrical Storage Battery Co., of Millwall, London. This, if not the first, was among the first attempts to use the storage battery as the source of energy for locomotion.

During the period 1888 to 1893 occasional attempts were made to apply this idea practically, but not much was achieved along useful lines. The progress during the next 15 years was slow, and little success was achieved. Therefore, the last two decades may be considered the successful development period of the storage-battery locomotive.

In coal mining, the application of the storage-battery locomotive is chiefly in gathering service in competition with animal or cable-reel locomotives. The locomotive delivers empty carsto the rooms or working places where the coal is being mined and hauls the loaded cars from the rooms. The length of haul depends upon the distance of the junction point from the active workings of the mine. As a rule the haulage from the junction point to the foot of the shaft or bottom of the slope is done by trolley locomotives, but in some instances where the grades permit this main-line haulage work is performed by storage-battery locomotives.

As the place storage-battery locomotives occupy with respect to safe haulage in gassy mines appears to be misunderstood, it is the purpose of this paper to clarify this point.

Those who originally designed storage-battery locomotives had no thought of safety in mind and it is just as well that they did not, as these early types of storage-battery locomotives with open controller, open motor, open rheostats, flimsy headlights, and crude wiring were very dangerous electrically and not at all suitable for use in a gassy mine. These locomotives, however, were placed in mines in which open lights were permitted and they replaced considerable animal haulage. Later they were gradually introduced in mines where closed lights were used, but in most cases these mines were not extremely gassy.

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1 This article is not subject to copyright. Reprinting, with customary acknowledgment to the Bureau of Mines, will be welcomed.

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Safety engineers gradually began to consider the possibilities of so changing the design of storage-battery locomotives, which were becoming a standardized product, that they might be used with reasonable safety in gassy mines. A locomotive of this type was visioned as far back as 1915. Representatives of locomotive manufacturers and engineers of the Bureau of Mines cooperated in preparing tentative standards for such equipment, and in November 1919, a formal standard known as Schedule 15 was finally issued.

The first approval under this schedule was issued March 14, 1921. Nearly every manufacturer of locomotive equipment entered the field and designed permissible storage-battery outfits. At present, eight companies have a total of 19 approvals for locomotive equipment. Two manufacturers have approvals for power trucks.

The simplicity and safety of this kind of equipment have improved continuously. Battery-box covers, which were weak, have been materially strengthened and mechanical means adopted for handling these heavier covers. The wiring between accessories has been simplified and better schemes adopted for its mechanical protection. Improved design of battery jars and battery plates has resulted in much longer battery life and in more reliable service. A better understanding of battery installation has resulted in less breakage of jars.

The Bureau of Mines from the first has looked upon the permissible-type storage-battery locomotive with favor because of its inherent safety advantages. That its energy is self-contained and limited to the immediate zone of the locomotive is a safety factor of great importance. In the trolley type of equipment one necessarily uses the track return, and the danger zone from the return corrent may extend throughout the mine. Poor bonding or no bonding may force the return current back toward the face. A storage-battery locomotive does not use or need the dangerous overhead trolley with its constant shock menace and fire hazard, and with the possibility of trolley or feeder circuits becoming a factor in ignition of gas or coal-dust. The trolley is an alleged cause of some very serious disasters. A storage-battery locomotive does not depend upon a trailing cable, a fact again very much in its favor. Although trailing cables have been allowed on permissible equipment, they are a constant source of worry and are the weakest link in the bureau's approval system. Locomotives that depend upon a trailing cable use a trolley pole after they leave the immediate zone covered by the short length of cable. Hence, much of this work produces the trolley arc which is dangerous if gas accidently accumulates anywhere along the trolley wire, as occasionally happens. The permissible-type storage-battery locomotive can operate at any part of a mine with the same factor of safety, and at night or any time when not in operation it can be brought to a point of absolute safety; whereas, with a wired system the wire must be left behind and exposed to all the hazards of roof and timber falls.

In summing up the situation certain facts can be enumerated:

1. Early types of storage-battery locomotives were crude in design and not too satisfactory in operation; also, no attempts were made to make them safe.
2. Such open-type equipment is still unsafe for use in gassy mines.

3. Permissible storage-battery locomotives, brought out under the joint endeavors of the locomotive manufacturers and the Bureau of Mines, show great improvement over early designs.
4. Such locomotives have been developed by nearly every locomotive manufacturer and are now available to operators.
5. The permissible storage-battery locomotive offers a high order of safety, and it has certain inherent safety advantages not common to any other type of equipment.
6. The Bureau of Mines strongly advocates the use of permissible storage-battery locomotives for haulage in gassy mines.

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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

HAZARDS IN CONNECTION WITH CONCENTRATED COAL MINING[1]

By D. Harrington[2]

Records indicate that to date fewer than 200 of our approximately 7,500 coal mines (less than 3 per cent) are using the newer or concentrated mechanical mining systems, and of these operations it is improbable that as many as 50 produce full tonnage from the newer systems; in many mines listed as using the newer or concentrated methods, more than 75 per cent of the output comes from the older parts of the mine where the old methods are employed. In 1925 the total coal tonnage from the newer methods for the United States is given as a trifle over 6,000,000, or a little over 1 per cent of the tonnage of the United States, and it is probable that 1927 tonnage from these methods was under 10,000,000. Hence it is seen that the concentrated mechanical methods are in their infancy, and it seems that this should be an opportune time to point out some of the pitfalls to safety that are likely to be encountered, with the idea of helping to prevent accidents or disasters and not in any degree with intent to prevent the spread of the mechanization of mines or concentration of mine workers or mine workings.

In the introduction of concentrated systems of mining largely dependent upon the assumption of much of the burden of underground work by mechanical contrivances, with consequent concentration of work and of the working force, in general but little attention has been paid the element of safety. Discussions of mechanical drilling, cutting, loading, conveying, hauling, etc., have ordinarily been characterized by an assumption (which is inferred rather than uttered) that safety will be enhanced rather than in any manner retarded or lessened by concentrated mining methods and devices. There have been a few attempts to show that mechanical mining is safer than are the more primitive ways of doing underground work by man power; a few figures or brief statistical records have been advanced tending to indicate that the concentrated systems using mechanical devices have actually shown fewer accidents per 100,000 tons of coal produced than has been the case in the same mines or mining regions when the older hand methods were utilized.

There have been, however, a number of places where the concentrated systems have had to be abandoned, chiefly on account of the safety element; and there is much probability that some of these systems which in themselves are or can be made to be reasonably safe will fall into disrepute because of failure of those in charge to use reasonable care to keep the work and workers safe. In fact one State

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inspection force has already put a ban on the use of a certain type of scraper system, another has openly voiced opposition to long faces, and a third has barred methods or systems that require the driving of single entries. While there are plenty of good and sufficient reasons why the newer or concentrated systems using mechanical rather than man power can, will, and should be used in our mines, there is absolutely no justification for attempting to utilize these newer ideas without the taking of common-sense precautions looking to the safety of the mine and of the miners as well as to lower costs and to increased tonnage.

Generally it is futile to discuss dangers unless there can be given some specific cases of occurrence of accidents; unfortunately, notwithstanding the newness of this type of work there is no dearth of such instances in connection with mechanical mining or with so-called concentrated systems. A recent explosion in Wales has been blamed upon methane ignition by a conveyor, and while the proof is not as definite as one would like, on the other hand the methane accumulation in this mine is very likely to have been caused by the lax methods of ventilation that only too generally accompany the newer mechanical systems. The explosion was not very violent or widespread, but it killed 51 men because of their being concentrated around the conveyor work.

In a pitching seam in the western part of the United States methane was ignited from an open electric motor on a face conveyor and 11 workers were killed; this affair also illustrates one of the inherent dangers of concentrated systems, since this gas ignition extended only a few hundred feet and produced practically no violence, and the 11 men were killed because of their being concentrated within approximately a 200-foot length of conveyor, and it is probable that the flame from this ignition would have caught only the usual one or two workers if it had occurred in the ordinary room of the older method of work. Here again was the sluggish ventilation which accompanies the new or concentrated systems so often that it seems inherent to them.

In a southern mine nine workers along a scraper face were killed on an off shift while timbering, undercutting, etc., to prepare for the oncoming shift, and in this instance the gas was probably ignited by an open light; again, there was merely a local inflammation with little or no violence, and again, lax ventilation methods were used. The large death list was, moreover, due to concentration of workers in a small area, and under the room-and-pillar system only the usual one or two room workers would probably have been caught.

In a western mine of fairly large capacity which had a record of no fatalities over a comparatively long period, a conveyor system was installed in one place, and within a year there had been three fatalities, one at a time, in the one working place served by the conveyor; here the trouble seemed to be largely a matter of too much noise by the conveyor, the workers being unable to hear the usual slight warning noises preceding the falling of rib or roof material when the older method of working was utilized. The occurrence of accidents when excessive noise at working faces drowns the noise of props or roof failing is difficult to avoid; face machinery should be kept well oiled and in good repair and should be stopped at intervals to allow surrounding conditions to be ascertained. Water used to wet the coal tends to reduce the noise from conveyors, scrapers, loaders, etc.

In another mine in which a scraper system was handling the coal from a long face of about 300 feet, coal had been removed from a comparatively large area and the overlying material was held by props when a mass of overlying sandstone about 150 feet in length and 20 or more feet in width with a thickness of 10 or more feet fell without warning and caught two men; it developed that the mine foreman had examined the place less than one-half hour previous to the fall and found it apparently safe, there being no evidence of undue weight on the props, nor could the impending fall be detected by the usual roof-sounding methods. In this case undoubtedly too much reliance was placed upon the comparatively solid roof and upon props to hold the roof; props are far too often relied upon to hold safe the places where there is concentration of numerous workers, and in general it would be decidedly safer and in the long run cheaper and more efficient if cribs rather than props were used where numerous workers are assembled in long-face work, whether with conveyors, scrapers, loaders, or otherwise.

One of the most alarming features about the newer systems of mining is the laxity in connection with ventilation, the above-mentioned explosions at long faces being examples; and one of the worst forms of the tendency to resort to ventilation makeshifts in the newer type of work is the use of blower fans and tubing in supposedly ventilating coal-mine faces. There have been numerous disasters due to the use of these fans in coal mines, and recently four men were killed in consequence of methane ignition where an entry-driving machine working face was forced to rely upon a blower fan and tubing for ventilation; there was the usual daily methane accumulation which must be expected upon coming on shift in the morning after the blower has been shut down since the previous shift the night before, and the methane in this instance was ignited either by electricity or by open lights.

Carelessness in the use of electricity in connection with scrapers, conveyors, loaders, fans, etc., is the rule rather than the exception; comparatively recently four men, one after another, were killed while trying to move an electrically driven blower in a mine, and in another instance a worker was killed upon coming in contact with an open knife switch controlling electric current to a small blower fan. These electrical accidents are by no means infrequent; they are likely to become increasingly numerous, and their elimination is one of the real problems in connection with the newer mining systems.

Probably the most dangerous feature as concerns safety when these concentrated methods are used comes from the fact that it frequently, if not generally, is considered necessary to complete a full cycle of operations daily if the methods are to be successful; and to complete this cycle of operations each day mining men appear to be willing to cast aside one precautionary practice after another long determined as necessary to keep mines safe; in fact, it is frequently found that practices are used in the mechanized sections of a mine which would not be countenanced in the other parts of the same mine which are using older systems of working. Below are given some of the hazards noticed where the newer systems are being used:

1. In a conveyor or electric loader system operation one usually finds open arcing types of electric motors, switches, etc., at or very close to faces which give off or are at any time likely to give off methane; wires poorly insulated or bare are poorly placed and poorly supported, and only too frequently the wires lie on the floor and workers are expected to "watch their step" when walking around.

2. Much dust is thrown into the air in connection with conveyor or loader work, the very fine (hence most dangerous) dust settling on adjacent surfaces, especially in the open region from which the coal has been removed; therefore in case of a fall of roof in that open region there are likely to be forced over the open arcing electrical equipment not only clouds of fine dust but also methane.

3. Frequently blasting is done during the working shift, and it is not at all uncommon to see 50 or more pounds of explosive with 25 or more detonators on the floor within a few feet of electric wires or motors or the open lights of workers; nor is it uncommon to see numerous blasting holes loaded ready to blast with workers using open lights and electrical equipment in operation close by.

4. When shots are fired during the working shift the workers are withdrawn only a short distance, hence in case of a blown-out shot or gas ignition from blasting the workers are likely, in fact are almost certain, to be killed or at least seriously injured. In blasting during the shift usually permissible explosives are employed, but only too frequently this good feature is partly nullified by using fuse instead of electric blasting or by shooting several holes at a time electrically (a poor practice, especially where men are in the mine). In some instances black blasting powder is used in this blasting during the shift, and this is little less than criminal, especially where the black blasting powder is tamped with coal dust and detonated by fuse or squibs.

5. In the hurry to complete the cycle of operations (upon returning after a blast) a minimum of attention is given inspection of the face region for methane or examination of roof conditions, and timbering is done before resumption of work only when absolutely necessary.

6. Under some roof conditions an appreciable length of time elapses after blasting before the roof will actually fall in pillar or long-face work, and where there is an "urge" to complete the cycle of operations little or no time is spared to await action of the roof, hence there are likely to be (and in fact there have been) accidents from falls of roof from this cause; much if not all of this hazard is escaped in ordinary room-and-pillar work, where shooting is or should be done after the working shift or at the end of the shift.

7. Generally reliance is placed upon props (frequently with very few props in position) to hold the roof (even with an extensive worked-out area) or to determine the line of break in the roof; in most cases props are entirely inadequate for this service, and in the long run are more expensive than would be an adequate system of cribs.

8. Scrapers, mechanical loaders, and, to a smaller extent, conveyors tear out props or cribs, and only too frequently operations are kept going irrespective of dangers caused by the removal of the roof supports, leaving the props or cribs to be replaced or not, as may be determined later on by the boss or the timberman.

9. There is generally very little clearance or adequate guarding of moving or electrically-charged parts around mechanical equipment near face regions, and workers have a minimum opportunity to travel without being injured.

10. Mechanical equipment, such as electric drills, blowers, mining machines, loaders, conveyors, and scrapers, is noisy, hence while in operation at or near face regions the noise from the equipment prevents the workers from hearing the more or less slight warning sounds generally given before a roof or rib falls; this is decidedly serious, inasmuch as the newer systems, with their concentrated, more or less continuous attack keep the roof and rib almost continually moving, and the worker is practically deprived of his main warning of danger because of the noise of the machinery.

11. The advocates of nearly every so-called concentrated system give reason after reason why it is essential that single entries of various lengths are necessary, and each advocate advances reason after reason why single entries of 200 to 1,000 or more feet are safe, notwithstanding that it has been one of the axioms of safe and sane coal mining that under no circumstances should any single underground opening be driven to a length of more than 200 feet; it is true that in many instances in the past single entries longer than 200 feet have been driven, but it is equally true that many disasters have resulted from this and it is also true that several such disasters have occurred in recent years. Moreover, the driving of single entries is not necessary to the success of practically any methods new or old, notwithstanding voluminous arguments to the contrary.

12. One of the worst makeshifts to which resort is had in this single-entry driving is the use (or rather the flagrant misuse) of blower fans and tubing for ventilation, notwithstanding the fact that these units are operated only during the working shift; hence methane is almost certain to accumulate at the faces during 8 to 16 hours per day. Moreover, these units are almost invariably poorly installed, especially as to electric wiring and fireproofing, and many fires and electrocutions as well as explosions have occurred and undoubtedly will occur from these installations.

13. Under stress of completing the cycle of operations in the concentrated systems there frequently is no hesitancy to allow (in some instances practically to force) workers to work around or under missed shots or to work in close proximity to missed shots while these are being removed or otherwise handled.

14. When rock or extra-large pieces of coal are brought down by blasting or happen to fall in such manner as to impede the operation of conveyors, loaders, scrapers, etc., there is little or no hesitancy in many mines to use the quick, lazy, and decidedly dangerous "adobe" or "sand-blast" shot rather than take the necessary time to remove the impediment safely by drilling a hole and using inert

stemming with electric blasting with the shift out of the mine. It is futile to state that permissible explosive is used in these "adobe" shots; any "adobe" shot is dangerous, and "adobe" or "sand" blasting should be prohibited in any coal mine at any time. Most certainly no "adobe" or "sand-blast" shot should be fired in any coal mine when a working shift is in the mine.

15. Economically, the weak point in most of the concentrated mining systems centers in haulage, and here again safety is sacrificed. Trolley locomotives and trolley-locomotive wires are brought almost up to dusty or gassy faces, and open-type cable-reel locomotives or open-type storage-battery locomotives are sent to similar places. In most mines the haulage system is "swamped," and on the other hand, in order to keep haulage as well as mechanical loading equipment working full time, some mining companies do not hesitate to attack the full length of a 200 or 300 foot room pillar in several places, with utter disregard of probable squeezes, bounces, roof falls, etc., and wholly without reference to anything like a uniform pillar line.

16. One of the safety advantages claimed by adherents of the newer concentrated systems is that of more intensive supervision; yet in many instances the work is placed in charge of some young electrician, mechanic, or engineer who knows little and cares less about haulage, timbering, blasting, ventilation, etc., though he is intensely interested in the electrical or mechanical details of the equipment. Frequently this new type of work is tried out in a part of a mine using the older system, and the direction of the new work is left in the hands of the usual old-time foreman who is inherently opposed to anything he has not been accustomed to doing. In both cases the new work is likely to fail, and it will be most unusual if failure is not hastened by accidents to workers, these accidents being wholly unnecessary. The greatest possible care should be exercised in selection of actual supervising officials for this new type of work at all times; and they should be able, experienced in underground mining, preferably with technical training, and most certainly in hearty sympathy with the idea of making the new system successful not only from the viewpoint of efficiency but also that of safety. In general there should be one boss of the above type for about each 25 underground workers. This matter of constant, effective supervision immediately "on the job" is one of the most essential cogs in making the new systems of mining a "go."

17. Most of the conveyor, scraper, or loader systems demand that the coal be in fairly finely divided form and that it be thrown well out from the face; to accomplish this, comparatively large charges of explosive are used, in some instances the charges of permissible explosive exceeding the permissible limit of 1 1/2 pounds per hole. These excessive charges are dangerous in that they are more likely to precipitate blown-out shots or cause explosions than would charges within the permissible limit of $1\frac{1}{2}$ pounds per hole; in addition, the excessively large charges have a decidedly harmful effect upon the roof and tend to increase accidents from falls of roof.

18. The newer systems with long faces require the drilling of numerous holes (10, 20, or more in some cases) for blasting, this being many more than in the ordinary room or entry face, with its 3 to 5 holes. Where the holes are hand drilled the workers are prone to drill as few as possible, since hand drilling of blasting holes is decidedly laborious; this automatically results in forcing the heavy loading of the comparatively few holes drilled, and this is in many cases the cause of heavy loading of holes even when it is not necessary to blast the coal into smaller sizes for subsequent handling.

19. One of the most essential features in safe operation of concentrated systems and one most difficult of attainment is to have ample illumination; under no circumstances should open lights be allowed, and ordinary types of incandescent lighting are dangerous for use at or near faces likely to be gassy or dusty. The safest lighting available is that of storage-battery lamps of the permissible type.

20. One feature of the concentrated intensive mechanized systems of coal mining that should occasion alarm is the fact that these systems generally cause practically continuous operation of electrical equipment at or very close to faces that are gassy or dusty, and this continuous use of electrical equipment at the face throughout the shift is decidedly more dangerous than the more or less intermittent use of mining machines or electric locomotives under older systems; even the latter equipment is dangerous in the older systems unless adequately safeguarded. It is significant that during the past few years ignitions of gas or dust by electricity, with resultant explosions, have jumped to more than 50 per cent of our serious coal-mine explosions, while electrical ignitions constituted less than 10 per cent of the causes of the initiation of major explosions during the period 1910 to 1924.

RECOMMENDATIONS AS TO SAFE OPERATION IN CONCENTRATED OR MECHANICAL SYSTEMS OF MINING

1. Where concentrated systems of mining are used, there should be ample, competent supervision; as a minimum there should be at least one supervising official or "boss" in constant attendance for about each 25 underground workers. These immediate, "always on the job" bosses should be experienced in mining as well as have a good working knowledge of electricity, machinery, and handling men.

2. It should be known to a certainty that those in actual charge of underground operation of the concentrated systems are in full sympathy with the system, at least in so far as giving it a fair square trial is concerned.

3. Ventilation should be even more carefully planned and conducted to and past working faces than where older systems of work are used. In a coal mine, under no circumstances should single entries be driven longer than 200 feet and under no circumstances should reliance be placed on any form of intermittent ventilation, such as is almost invariably found where blowers and tubing are used.

4. None but the safest available types of electrical equipment, wiring, and installations should be allowed when mechanical work is being done at or close to face regions; this is true even where no explosive gas has been found.

a. Wiring should be thoroughly insulated, well supported, and strung along the rib or other place, as far as feasible from probable contact with workers.

b. Bare or poorly insulated wires or open electrical switches should not be placed along or even fairly close to the roof in parts of a mine where methane may accumulate if ventilation is interrupted.

c. Only permissible electrical equipment should be used at or near faces that are or are likely to be gassy or dusty. Open types of electrical equipment, such as conveyor or hoist motors, trolley or cable-reel locomotives, drills, etc., are decidedly dangerous when used near working faces from which coal dust is given off and are much more dangerous when explosive gas also may be present.

d. Incandescent electric lights and light wires are dangerous when used at or near faces that are or are likely to be dusty or gassy. Only up-to-date permissible storage-battery lighting should be used.

e. Although open-type electric motors or switches or bare electric wires should not be allowed at or near faces that are or may become dusty or gassy, it is realized that such equipment is being and probably will continue to be so used, and it is suggested that such equipment is much more likely to be partly safe if kept fairly close to the floor rather than close to the roof, the latter being the usual practice.

5. There should be ample, safe clearance for workers around mechanical equipment used at or near faces, the clearance being such that workers are not required to pass over or under moving or electrically charged equipment with the possibility or probability of being injured when so doing. Moving belts, gears, etc., on equipment used at or near face regions should be safely protected by adequate guards.

6. The noise made by machinery makes it difficult, if not impossible, to hear the usual warning sound given by overhanging roof or rib material before it falls. Every feasible means should be taken to reduce noise where mechanical equipment is used at or around face regions; in connection with certain types of mechanical equipment such as conveyors, the use of water not only tends to reduce noise but also aids materially in reduction of dust in and around the equipment and in the general surrounding atmosphere.

7. In general, it is much safer and even less expensive to protect concentrations of workers in the newer systems by use of cribs (which may or may not be removable) rather than to depand upon props. Props should be used as an auxiliary to the cribs or as to supplement the cribs.

8. When timber at or around mechanized faces is torn out by machinery or by blasting, there should be no delay in its replacement, even when such action may cause temporary interruption of the usual coal-producing work.

9. After blasting there should be no hesitancy in taking sufficient time to place timber before allowing the loaders to start operations. Many accidents occur through overeagerness to start loading as soon as possible after blasting, practically irrespective of roof conditions.

10. Where at all feasible no blasting should be done when the working shift is in the mine, and all blasting in coal mines should be done by competent shot firers using only permissible explosives shot electrically, with not over $1\frac{1}{2}$ pounds of explosive per hole and with holes well tamped with incombustible matter (in other words coal-dust should not be used for stemming). By far the safest method of coal-mine blasting is that where all explosive is held out of the mine during the working shift and all holes are loaded by shot firers after the shift and are fired electrically from the surface with all persons, including the shot firers, out of the mine.

11. While the above methods of blasting are absolutely practicable in addition to being safe, it is recognized that many concentrated mechanized systems are dependent upon being able to blast at any time; hence the following recommendations are given as to blasting practice when the working shift is in the mine, with the intent to safeguard as much as possible a practice known to be inherently unsafe:-

a. All holes should be loaded and fired by shot firers.
b. Only permissible explosive should be used in a coal mine, whether to bring down coal or to shoot rock. Certainly no black blasting powder or dynamite should be used in any coal mine while any men are in the mine. No hole should be charged with more than $1\frac{1}{2}$ pounds of permissible explosive, whether the men are in or out of the mine, and a sufficient number of holes should be provided to allow using less than $1\frac{1}{2}$ pounds of explosive per hole.
c. Blasting should be done by permissible single-shot electric blasting units.
d. All holes should be tamped with inert stemming.
e. There should be no solid shooting of coal or "adobe" blasting of coal or rock.
f. Holes should not be loaded and tamped while workers other than the shot firers are closer than 25 feet.
g. Under no circumstances should holes be loaded while electrical equipment, such as electric drills or electric coal-cutting machines, is working within 25 feet.
h. Preferably the face region should be well wet down before blasting.

i. Workers should be withdrawn at least 500 feet before blasting, and ample warning given haulage and other adjacent workers; and loaders and other face workers should not be allowed to return after the blast until the face which has been blasted has been given a careful examination by a competent fire boss for explosive gas as well as for roof conditions or possible missed shots. It is important that ample time be given the above inspection to make it a thorough one; otherwise, there are certain to be numerous disasters in the concentrated working of coal mines. Likewise ample time should be taken to remove any dangerous condition before workers are permitted to resume loading and like operations.

j. Where shots fail to detonate, loaders and similar workers should not be allowed within 50 feet of them until these shots have been fired or the charge has been removed from the hole.

k. It is recommended that if the CO_2 method of blasting now in use in a few Indiana and Illinois mines proves safe and efficient this method or one similar to it be substituted for the usual types of explosives where it is considered necessary to blast while the working shift is in the mine.

12. With the concentration of workers and of tonnage effected by the newer systems there should be ample opportunity for better rather than the poorer ventilation usually found at the places of concentrated work, as compared with the greater scattering of workers and working places under the older systems.

a. As heretofore stated, single entries longer than 200 feet should not be allowed under any circumstances. They are difficult to ventilate, and in case of a fall men are likely to be trapped.

b. Blower fans and tubing should not be allowed in any coal mine; however, it is recognized that they are being used and probably will continue to be used, and the following requirements should be kept rigidly in effect if this equipment is to be kept in even reasonable safety.

1. They should be kept in operation 24 hours per day.
2. The region surrounding a fan should be securely fireproofed, particularly if the fan is electrically driven.
3. Electric wiring around the fan should be well insulated and well supported.
4. Electric switches at or around the fan should be of enclosed type.
5. Preferably the fan should be operated by compressed air.

6. The fan should be located in strictly intake air and under no circumstances nearer than 300 feet to a face likely to give off methane.
7. The tubing should be fireproof or at least fire resistant, and it should be adequately supported from the roof and under no circumstances lie along the floor.

c. Workers should be withdrawn from any place or face where electrically driven machines are in use when the methane content is over $1\frac{1}{2}$ per cent.

d. When a fall cuts air circulation from any working face using concentrated mining no workers should be allowed in the region (other than a limited number to restore air circulation) until ordinary ventilation has been restored. This seems an unnecessary recommendation; yet cases occur where the desire to complete the cycle of operations leads to the forcing of work even when conditions are known to be dangerous.

13. No nonpermissible electric locomotives should be allowed close to any face which gives off or is likely to give off methane; this includes cable-reel and nonpermissible storage-battery locomotives.

14. Under no circumstances should trolley locomotives be used in return air or within 300 feet of any face that gives off or is likely to give off methane or within 100 feet of any place where explosives are being used to charge drill holes.

CONCLUSIONS

There is every reason for belief that mechanized concentrated methods of mining present numerous advantages and that they will spread fairly rapidly through the coal-producing industry of the United States. There is no question that these methods are now in many instances being used unsafely and unwisely, and there is also no good reason why they can not be made safe. On the contrary, most of them can and should be made safe, and the sooner the unsafe methods and practices are discarded the fewer disasters there will be.

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May, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

EXPORTS OF MINERAL OILS FROM GULF COAST PORTS IN 1927[1]

By

Arthur H. Redfield[2]

Less gasoline and kerosene were exported in 1927 from New Orleans, Sabine, and Galveston to the United Kingdom, France, and Italy, than in 1926, and more to the smaller countries of Europe. Sales of fuel oil and gas oil to Europe, to Central America, and to the West Indies increased. Canada, Cuba, Spain, and Germany bought more crude oil from the Gulf Coast.

As in previous years, 48 per cent of the gasoline and 46 per cent of the kerosene exported from the United States in 1927 passed through New Orleans, Sabine, and Galveston; but these ports handled only 20.3 per cent of the national exports of fuel oil and gas oil in 1927, as compared with 36 per cent in 1924 and 51 per cent in 1921.

Western Europe received more than nine-tenths of the 20,458,477 barrels of gasoline exported in bulk in 1927. Five-sevenths of these shipments went to the United Kingdom, France, the Netherlands, and Sweden. Of the 806,099 barrels of gasoline exported in containers 42 per cent went to South America, chiefly to Argentina, Brazil, and Uruguay; 29 per cent to Australia and New Zealand; 12 per cent to Africa; nearly 9 per cent to the Far East; and the rest to the Caribbean region.

Nearly 81 per cent of the 7,796,553 barrels of kerosene exported in bulk from the Gulf coast in 1927 was shipped to Europe, chiefly to the United Kingdom, the Netherlands, France, Germany, and Belgium. Fifteen per cent went to British India, and most of the remainder to Algeria and Tunisia, and to China. Of the 1,159,260 barrels of kerosene exported in containers 43 per cent was shipped to Asia, chiefly to China, Hong Kong, and Kwantung, and to the Philippine Islands. More than 24 per cent went to South America, principally to Argentina, Brazil, and Uruguay. Africa received 15.6 per cent; Australia and New Zealand 10.7 per cent; and the Caribbean region 6.1 per cent.

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The following figures, expressed in barrels of 42 gallons, were compiled from statistics of the Bureau of Foreign and Domestic Commerce:

Crude Petroleum Exported from New Orleans, Sabine, and Galveston, 1923-1927.

	1923	1924	1925	1926	1927
Belgium	30,163	59,749	38,088	35,433	79
Czechoslovakia	- - -	- - -	23,044	- - -	- - -
Denmark	- - -	65,151	- - -	- - -	24,331
France	28,608	7,560	- - -	61,614	20
Germany	253,231	319,501	547,424	17,521	94,101
Italy	18,238	118,799	72,213	- - -	- - -
Malta, Gozo, & Cyprus	30,000	- - -	- - -	- - -	- - -
Spain	4,557	- - -	64	37,869	117,618
United Kingdom	- - -	439,000	144,706	61,801	68,945
Canada	1,450,234	769,214	400,000	256,109	597,282
Guatemala	- - -	- - -	- - -	- - -	35,416
Honduras	1	- - -	32,143	36	- - -
Panama	108,238	76,376	- - -	- - -	- - -
Mexico	196,459	274,037	743,919	1	27,968
Cuba	331,851	1,028,914	928,204	434,180	526,816
Dominican Republic	- - -	53,568	53,221	- - -	- - -
Dutch West Indies	- - -	126,459	- - -	- - -	- - -
Argentina	- - -	208,806	- - -	190,895	32,798
Chile	- - -	64,780	- - -	- - -	- - -
Other countries	14	78	65	- - -	47
Total	2,451,594	3,611,992	2,983,091	1,095,459	1,525,421

Gasoline Exported from New Orleans, Sabine, and Galveston, 1923-1927.

	1923	1924	1925	1926	1927
Belgium	468,277	701,428	912,622	792,878	867,952
Denmark	49,167	46,548	188,022	274,122	426,514
France	3,472,003	4,532,871	5,156,537	6,494,899	5,415,869
Germany	135,058	419,748	458,142	600,264	554,684
Irish Free State	- - -	23,078*	- - -	178,865	41,704
Italy	239,129	573,616	604,181	856,891	510,194
Netherlands	204,316	465,577	554,235	1,277,309	1,275,727
Norway	51,190	- - -	32,328	222,653	151,312
Spain	368,836	567,580	559,414	607,857	867,344
Sweden	210,410	175,978	282,007	425,974	1,021,538
United Kingdom	2,276,449	3,333,158	4,133,578	9,336,885	7,561,160
Canada	22,717	102,747	200,001	240,838	208,283
Cuba	88,250	55,388	90,259	721,552	440,196
Argentina	330,972	179,071	276,724	262,027	133,604
Brazil	193,945	305,884	442,933	461,541	403,456
Australia	105,688	139,047	141,168	135,664	158,703
Union of South Africa	37,085	48,429	69,555	50,495	165,297
Other British S.Africa	- - -	- - -	3,576	72,611	222,805
Egypt	7,074	- - -	- - -	39,972	111,621
Algeria and Tunisia	150,432	128,451	151,189	188,510	133,744
Other countries	241,085	418,241	589,887	483,646	592,869
Total	8,652,083	12,216,840	14,846,358	23,725,453	21,264,576
Shipped in bulk	- - -	- - -	14,116,347	22,968,788	20,458,477
Shipped in containers	- - -	- - -	730,011	756,665	806,099

*Ireland.

Illuminating Oil (Kerosene) Exported from New Orleans, Sabine, & Galveston, 1923-1927.

	1923	1924	1925	1926	1927
Belgium	183,000	286,780	416,531	316,774	390,075
Denmark	69,993	67,976	166,828	219,682	90,400
Finland	210,586	118,218	145,290	32,885	77,380
France	1,616,265	1,671,249	947,124	1,756,370	857,680
Germany	243,052	527,824	742,210	479,297	518,488
Irish Free State	97,635*	161,240*	31,470	211,924	189,520
Italy	84,814	245,919	162,235	399,823	- - -
Netherlands	919,918	998,352	953,526	1,449,797	1,431,074
Norway	193,464	59,962	127,636	85,532	148,795
Portugal	- - -	23,486	- - -	20,289	144,642
Spain	58,165	101,044	82,282	122,154	68,326
Sweden	250,751	91,041	108,134	107,070	190,620
United Kingdom	1,230,835	1,782,873	1,411,136	2,225,104	2,089,489
Brazil	118,811	125,213	120,754	128,750	134,067
British India	923,344	878,455	1,078,108	1,069,310	1,177,632
China	1,109,597	443,527	497,273	627,478	514,502
French Indo-China	- - -	- - -	131,731	- - -	- - -
Kwantung	174,966	179,290	20,238	47,061	35,644
Australia	148,753	109,792	148,348	98,500	108,982
Egypt	173,186	53,869	57,574	30,024	- - -
Algeria & Tunisia	33,961	67,676	103,778	106,650	123,858
Other countries	631,621	632,083	778,898	575,443	644,639
Total	8,472,717	8,625,869	8,231,104	10,109,917	8,935,813
Shipped in bulk	- - -	- - -	7,050,859	8,977,949	7,796,553
Shipped in containers	- - -	- - -	1,180,245	1,131,968	1,139,260

*Ireland.

Gas Oil and Fuel Oil Exported from New Orleans, Sabine, & Galveston, 1923-1927

	1923	1924	1925	1926	1927
Belgium	165,531	237,919	418,595	277,548	359,199
Denmark	402,432	277,656	351,107	319,816	515,457
France	678,116	614,855	333,403	561,874	34,401
Germany	845,115	698,832	814,799	776,538	1,106,793
Italy	1,250,745	2,017,944	1,045,594	243,056	158,279
Netherlands	460,396	402,650	269,015	407,460	604,065
Norway	251,197	170,657	219,969	88,339	97,080
Portugal	118,980	51,357	18,569	158,267	47,005
Spain	109,183	298,676	184,771	197,495	37,273
Sweden	263,580	205,437	82,276	116,765	217,354
United Kingdom	2,972,896	3,195,985	3,444,014	3,188,532	3,958,178
Canada	315,206	41,986	140,065	63,564	41,271
Honduras	291	94,329	355,763	172,205	288,608
Panama	501,714	1,388,261	976,370	918,703	173,307
Mexico	1,151,521	1,798,055	240,056	326	53,369
Cuba	96,942	129,594	1,395,286	248,425	1,072,645
Dominican Republic	75,717	181,095	154,001	189,592	222,287
Virgin Islands of U.S.	- - -	- - -	152,659	43,000	- - -
Colombia	652	151,512	1,179	35,000	- - -
Belgian Congo	- - -	- - -	- - -	159,993	31,835
Egypt	49,703	681,544	105,449	- - -	- - -
Algeria & Tunisia	270,998	55,121	8,802	281,874	- - -
Other Portuguese Africa	- - -	- - -	- - -	- - -	103,457
Canary Islands	181,113	1,054	- - -	- - -	116,110
Other countries	425,015	695,592	392,136	421,932	358,546
Total	10,587,043	13,390,111	11,103,878	8,870,304	9,596,519

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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

FIRES AND FIRE PREVENTION IN LAKE SUPERIOR MINES[1]

By F. C. Gregory[2]

Metal-mine fires occur frequently, and are so full of possible danger to life and property that the subject of fire prevention is of continuous interest to everyone connected with mining. A review of the fire record of the Lake Superior district, noting the frequency of the fires, their causes, and the fire-prevention methods employed, should be of benefit to all. It is the purpose of this paper to consider as briefly as possible some of the fires that have occurred, their chief causes, and the fire-prevention measures and fire-fighting methods which some of the operating companies have adopted.

Changed methods of mining and fire-protection methods have in recent years effected a change in the causes and locations of underground fires. To bring this out, the fires are divided into two groups -- those before 1917, and those occurring during the period 1917-28. The earlier fires are mentioned only briefly, to emphasize the changing conditions.

Several operating companies furnished to the author as complete information as they could collect on fires in their mines. Their assistance, which makes this paper possible, is gratefully acknowledged. The list of fires given in Bureau of Mines Technical Paper 59, "Mine Fires in Lake Superior Iron Mines," by Edwin Higgins, was used to supplement information obtained on earlier fires.

EARLY FIRES OF THE LAKE SUPERIOR DISTRICT

In the following lists of fires only those caused by ignition of timber or other mining supplies are considered. The "black slate" or "sulphur" fires are treated separately further on. Forty fires occurring before 1917 are briefly summarized here.

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Summary of 40 Fires Occurring Before 1917

Place of Ignition		Probable Cause		How Fought	
Shaft	9	Candle	16	Burned Out	7
Shaft or Pump Station	13	Oil Lamps	4	Sealed	11
Shaft House	2	Carbide Lamp	1	Sealed & Water	2
Drift or Crosscut	5	Open Fire	1	Sealed & Steam	1
Sub-level	1	Oil Stove	1	Flooded	1
Stope	3	Power Torch	1	Water	11
Ore Chute	1	Sparks (surface)	3	Chemicals	2
Mule Barn	2	Electricity	2	Snow	1
Magazine	3	Lightning	1	Caved	1
Surface Cave	1	Spontaneous	1	Unknown	3
	40	Hot Ashes	1		40
		Smoking	2		
		Friction	1		
		Unknown	5		
			40		

The foregoing summary shows that formerly the shafts and the stations opening from the shafts were the danger points; 22 of the 40 fires originated in such places, and two other fires which started in wooden headworks ignited the shaft. The mule barn has been eliminated from among the other points of origin. Candles and oil-burning lamps were formerly the chief sources of ignition, and in this list they account for just half the fires; these causes have also been eliminated in our present-day mines.

The older methods of fire fighting are interesting in comparison with the more recent methods. Seven of the early fires were allowed to burn out. Eleven were sealed and allowed to smother; in most of these cases the entire mine was sealed for several days or weeks while the fire died out. According to the records oxygen breathing apparatus was worn at only two of the fires, and chemical fire extinguishers were used at only two.

Twenty-three lives were lost in the forty fires. One of the victims was a rescue man wearing an early type of oxygen breathing apparatus. The other men were suffocated by fire gases. There is no record of any man being actually burned. Most of the men lost were in parts of the mine distant from the fire.

RECENT FIRES OF THE DISTRICT

The first group of recent fires covers the period of many changes in the Lake Superior mines. Candles and oil lamps were discarded, and carbide lamps were universally adopted; electric-trolley haulage supplanted the mules, and electricity for many purposes was introduced; fire-proofing of shafts, shaft stations, and surface structures, using steel, concrete, and "gunite", became the general practice for new construction; and fire-fighting equipment, including oxygen breathing apparatus, was rather widely installed in the district. These changes are all apparent in a study of the fires of the second group, which comprises the fires of the last 12 years - 1917-28.

The 55 fires summarized below are those concerning which definite information was obtained. All of the serious fires are included, as well as many that were discovered and extinguished before gaining headway, but the list is known to be incomplete. A few fires that caused much damage are omitted because definite information as to cause is lacking, and many small ones are not listed because no record of them was kept. The list is large enough to show the principal causes of the fires and to allow the drawing of some conclusions about them.

Of the 55 fires, 11 caused a considerable loss of property, and seven interrupted operations in shafts. Two lives were lost. Eight other fires interrupted operations for a day or more. The other fires were discovered and extinguished before getting out of control.

Summary of 55 Fires from 1917-28

Place of Ignition		Probable Cause		How Fought	
Shaft	10	Electricity	22	Seals only	3
Shaft or pump station	6	Carbide lamps	5	Seals and water	9
Drift or crosscut	20	Paper torch	5	Seals, water and chemicals	2
Sublevel	6	Open fire	2	Seals and chemicals	3
Stope	2	Smoking	6	Seals and steam	1
Ore Chute	5	Oxyacetylene torch	2	Water	20
Ore Pocket	2	Friction	4	Chemicals	12
Raise	1	Slaked carbide	1	Ore	2
Explosives magazine	1	Spontaneous	1	Chopped out	1
Surface structures	2	Lightning	1	Flooding	1
		Unknown	6	Not given	1

Protection Used by Fire Fighters:

Oxygen breathing apparatus	21
All-Service gas masks	4
Apparatus and masks	2
None	28

Summary of Fires by Ranges and States

Range		States	
Vermillion	3	Minnesota	23
Mesabi	14	Wisconsin	3
Cuyuna	6	Michigan	29
Gogebic	16		
Minominee	2		
Marquette	6		
Copper Country	8		

Summary of Fires by Place and Cause

Place of Origin	Electricity	Smoking	Carbide light	Torch	Friction	Other	Unknown
Shaft	4	2			4		
Stations	3					3	
Drift or crosscut	11	2	3			1	3
Stope	1			1			
Sublevel	1	2	1				2
Ore Chute				4		1	
Ore pocket						2	
Raise	1						
Magazine			1				
Shaft house	1						1
	22	6	5	5	4	7	6

Electricity predominates as a cause of fire in mines, as the foregoing summary shows. The 22 electrical fires noted have occurred since 1921 and eight of them since the first of this year, thus showing an increase coincident with the extended use of electricity underground. Since electrical fires form such an important group they will be discussed more fully than the other classes of recent fires.

In looking for the particular electrical equipment that caused ignition, it was found that fires were attributable to:

1.	Main power circuits	3
2.	Trolley or lighting circuits	10
3.	Motor feed circuits	3
4.	Signal circuits	2
5.	Other electrical equipment	4

1. Two of the main power-circuit failures were caused by caving and movement of the ground. The third fire burned all evidence of its first cause.

2. Of the trolley and lighting circuit fires, two were caused by wiring improperly installed by others than the electricians; two were caused by crushing the timber caps against the trolley; one by leaving the trolley pole on the wire at the end of the shift so that the wire was held against a timber cap; two by failure of insulators; one by a spark from the trolley wheel when passing a frog, igniting dry lagging; one from an electric light in contact with inflammable material in a closed box; and of one the cause is unknown.

3. The motor feed circuit fires were caused by crushing of the timber.

4. Both of the signal circuit fires were due to broken insulation on the signal wires.

5. One fan motor, set close to a post, heated sufficiently to ignite the wood. The motor of a sinking hoist was left running and set fire to the timber foundation. The resistance coil for an electric tugger heated and ignited

the post on which it was hung; the controller was probably left "on" by the miner. Evidence was destroyed in the fourth case where a small transformer and resistance box burned.

Probably the most interesting of the electrical fires on record are five which were ignited by a 250-volt D.C. circuit in contact with timber.

A very unusual happening on one of the main power circuits was the parting of the connection in a junction box just enough to cause the box to heat and ignite the supporting timber. A slight ground movement placed sufficient strain on the cable to cause the parting.

Information at hand shows that six electrical fires resulted from carelessness of employees -- failure to shut off power from motors or throw sectionalizing switches, the installation of electrical wiring by unskilled men, and other violations of established rules. Improper methods of installing equipment or improper equipment resulted in three electrical fires. Failure of supposedly standard equipment caused three fires, and caving of ground caused six fires. Nine electrical fires occurred during a regular working shift and 11 of them started during an off-shift period. Most of the last group were discovered by repair crews or pumpmen.

Of the five fires started by the miners' carbide lights, three were started in old crosscuts or raises by timbermen who were hiding their tools at the end of the shift. Each of these three fires gained a considerable headway before they were discovered. Another fire of this group was started at the end of the shift, when a carbide lamp ignited a piece of canvas fan tubing. The fifth fire was started during the shift by contact of a lamp with drift timbers, and was discovered and extinguished by the mine foreman on his rounds.

Lighted paper torches thrown into ore chutes to estimate the amount of ore caused five fires which gained such headway that it was a real job to extinguish them. Oxygen breathing apparatus was used at three of these fires, which interrupted production for one or more days on account of gas.

Of the six fires caused by smoking, two occurred in shafts; one caused a considerable damage to property and closed the mine for several days, but the other was quickly discovered and extinguished. Two other fires of the six occurred in main drifts; both of these were out of control when reached and caused large damage to property. The last two fires started in sublevels, and whereas they did not cause very great property damage, both interrupted operations at the mines.

The four fires attributed to friction were all in inclined, timber-lined shafts, and were charged to overheated shaft rollers. Two of these fires resulted in large property losses.

Two fires that should be given careful consideration were caused by oxyacetylene cutting torches. This equipment is now used underground in many places for repair work both in shafts and chutes and in ore pockets. Timber covered with metal is apt to have decayed spots that will readily ignite from the intense heat of the oxyacetylene flame, and will smoulder for a considerable time before the fire becomes really active. The smoke which naturally accompanies this kind of work may mask the wood smoke until the crew has gone. One of these fires started in an ore raise and the other in a shaft pocket; they were not discovered until some time after the repair men had finished and gone.

Another unusual fire was that started by the chemical action of moisture on calcium carbide. In this case metal cans were provided at the underground stations to receive spent carbide. As the miners emptied their lamps before going to surface, evidently much unused carbide was also dumped. Near the end of the shift about 200 pounds of this waste material was dumped into the shaft pocket and two or three cars of ore were dumped on top of it. Ignition of the timber lining resulted. Fortunately the fire was discovered before the men were all hoisted. Even though the fire was buried under the ore, it would soon have gained headway.

Lightning started a fire by striking the cables leading to the electric pump. The high voltage burnt out the control in the underground pumproom and set fire to the wooden panel and supporting timbers. The starting of fires by lightning is very unusual. One fire started spontaneously in oily waste placed behind a wooden post in a timbered pumproom. Two fires started from small open fires, one for warming a pumproom and the other for heating waterproofing paint.

FIRE PREVENTION AT THE MINES

Much good work in fire prevention has been done by some of the companies, but it can only be outlined here. The fire-prevention work has resulted in a smaller number of fires in shafts and shaft stations, in a decrease in the percentage of serious fires, and, perhaps the most striking result of all, in a marked decrease in loss of life.

FIREPROOFING

Some of the factors involved in fireproofing a mine are:

1. The use of steel sets -- steel sets with concrete lath and reenforced concrete for shaft construction.

2. The installation of sprinkling systems in timbered shafts.

3. The use of gunite to fireproof shaft timber.

4. The use of steel, concrete, and gunite in shaft and pump stations and in explosives magazines.

5. The installation of steel sets in drifts as fire breaks, or the removal of timber and guniting of sections of rock drift.

6. Experiments with fire retarding timber preservatives for drift timbers.

7. Installation of special water lines for fire fighting in drifts and sublevels; placing special fire hydrants or regular drilling lines; interconnecting water and air-pipe lines; installing a special series of water tanks at shafts stations in deep mines to regulate pressure; providing adequate fire hose at underground stations.

8. General use of soda-acid and carbon-tetrachloride fire extinguishers at surface and underground stations.

9. The installation of special fire doors to sectionalize the mine.

10. The use of covered metal containers for oily waste, spent carbide, litter from explosives magazines, and other small inflammable materials.

11. Limiting supplies of oil, etc., underground.

12. Keeping the entire mine free from accumulations of rubbish, especially the magazines and stations.

13. Maintaining fire patrols in the mine between working shifts.

14. Adopting very rigid specifications for electrical supplies and installations.

15. Prohibiting or limiting smoking underground.

16. Providing a quick method of fire warning by stenches and mine telephones.

17. Maintaining mine-rescue stations and trained men.

18. Making special studies of fire hazards and having prearranged plans for emergencies, with definite organization, outlined instructions, and fire maps.

The foregoing list briefly covers the fire-prevention work upon which a great deal of thought and money have been expended. Some mines still have done very little toward fire prevention, but others have done everything listed above, and more. Fires that occurred in mines that were fully prepared for prevention have been extinguished with little loss of property and small risk to the fire fighters. Time does not permit a detailed discussion of all these preventive measures, but a few will be enlarged upon.

Disposal of Rubbish

The boxes, paper, and sawdust that go into the mines with blasting supplies constitute the largest source of very inflammable waste material that must be disposed of. Investigation shows that most of the mines hoist the sawdust and paper and dispose of it on the surface. About 75 per cent of the mines also hoist all explosives boxes and fuse cases shortly after they are emptied. Some of the top-slice mines break up the boxes, make the pieces into bundles, and place them in a room just before blasting; they thus become a part of the mat. In a few mines the boxes are left underground, where they are subject to ignition.

Metal containers are commonly used for oily rags and waste and for fine refuse from the magazines. Some companies provide metal cans at the shaft stations for spent carbide and for all small litter, so that there is no chance for such material to accumulate underground. Less attention is paid to the bark and chips that accumulate at the timber raises where piles of considerable size may often be found. Old timber from repair work is generally hoisted or placed in the mat; occasionally it is piled in unused crosscuts to decay and become a fire hazard.

Fire Doors

For the cost involved, a good system of fire doors is probably more protection to life and property than any other device. All main shafts at every level and all definite sections of the mine should be provided with doors so that they can be quickly shut off from the rest of the mine.

When there is a serious hazard to a shaft, the doors can be mechanically closed from the surface or various underground points. The Lake Superior district has fire doors of many types and of varied construction. There are concrete frames with steel doors, wooden doors protected with metal or gunite, and doors of unprotected wood. Although the fireproof construction is the most desirable, wooden doors will do good service until the fire reaches them.

Mine-Rescue Stations

With one notable exception, each mining district in the Lake Superior region is well provided with special mine-rescue apparatus and trained men. The various mining companies maintain in their mine-rescue stations 220 sets of two-hour type oxygen breathing apparatus and 65 All-Service gas masks. Bureau of Mines Car No. 8 carries 16 sets of oxygen breathing apparatus and 5 All-Service masks. In addition to these masks, some companies have gas masks that are not considered as part of the mine-rescue equipment, and most of the local fire departments have equipment that is available in emergencies, so that the total number of masks is well above 300 sets. The company-owned apparatus is located as follows:

	Sets
Vermillion Range	20
Mesabi Range	50
Cuyuna Range	--
Gogebic Range	65
Menominee Range	54
Marquette Range	35
Copper Country	61
Total	285

Most of the large companies and a few of the smaller ones maintain mine-rescue stations, employ their own instructor who carries on the training work regularly and have a regular crew of trained men. A few companies are still wholly dependent upon their neighbors in case of fire. Also some mines are dependent upon their own company stations which are located at a considerable distance.

The mine-rescue telephone, for use in fighting underground fires, was developed in the district and has been adopted by three companies as regular fire fighting equipment. It has been used at three fires and each time has simplified and made safer the work of the apparatus men.

The Lake Superior mines were among the pioneers in the use of oxygen breathing apparatus; the first equipment was purchased in 1911. As improved equipment has been devised it has been adopted, so that the rescue stations contain modern types of apparatus, All-Service masks, self-rescuer masks, the latest gas-detecting device, and supplies that have been proved of value in mine-fire work.

Mine-Rescue Training

Training in the wearing of oxygen-breathing apparatus and All-Service masks and in the rudiments of mine-fire fighting is still generally called "rescue training," as the possible saving of life is its first consideration. Mining companies take much interest in training work. It is believed that there is not an underground mine in the district without men trained in the use of breathing apparatus. Twenty-five company employees spend a part of their time keeping the equipment in shape and carrying on the training of the men. The Bureau of Mines instructors are kept busy with requests for training; they reach each mine in the district every second year. The exact number of men who have received training is not known. Over one thousand men have been trained in this work by the Bureau of Mines during the last three years, but they are only a part of the trained men in the district. The men are taught the construction and functioning of the oxygen breathing apparatus, All-Service mask, and "self-rescuer" type of carbon monoxide mask, are required to wear the protective devices in smoke and gas until they have confidence in them, are given instruction in the effects of fire gases, and are taken underground and taught the elements of mine-fire fighting. They are taught, especially, the limitations of the different types of protection, and how to take care of themselves and their team-mates in any emergency. Every rescue man knows how to administer artificial respiration.

As a result of the rescue training, men wore respiratory protection at 27 of the recent fires, and there were no serious accidents. In a few cases work was done in atmospheres that would have been quickly fatal to unprotected men and at great distances from fresh air.

Many of the operating officials and engineers are qualified mine-rescue men and have also taken the special course in fire-fighting work given by the Bureau of Mines, which teaches organization and procedure, gas sampling and analysis, control of ventilation, and other details of fire fighting.

Results of Fire-Prevention Work

With changes in the causes of ignition it is difficult to estimate just what effect the fire-prevention work has had on the number of ignitions. Taken at their face value, the figures given in the two summaries of fires show that fireproofing work done in the shafts and in the shaft and pump stations has prevented a number of fires. Nine of the earlier fires, or 23 per cent, started in shafts, and 13, or 32 per cent, in shaft or pump stations -- a total of 22 out of 40 fires, or 55 per cent, that started in such places. Attention to fireproofing and protecting these exposures started during the first period; the work is far from completed now, since 16 of the late fires had their beginnings in shaft or station. Ten fires out of 55, or 18 per cent, started in the shafts, and six, or 11 per cent, in shaft or pump stations -- a total of 16, or 29 per cent; this class of fires has been reduced almost one-half according to these figures. The reduction of fires starting in underground stations is particularly notable, and can be attributed both to fireproofing and to the care and removal of rubbish.

Property loss and probable loss of life certainly have been prevented by fire-fighting equipment and trained men. One-half of the earlier fires were either allowed to burn out or the mine was sealed to smother them and no further work done. Other fires were fought at great risk to the men. At only two of these earlier fires was oxygen breathing apparatus used. Twenty-seven of the recent fires were fought by men wearing apparatus or masks. The increased use of chemical fire extinguishers is also very marked; 12 fires were extinguished by them alone; they were used five times in conjunction with other methods. The use of brattices or bulkheads to seal off fires has not decreased, but the method of use has changed. If the fire is beyond direct fighting, the tendency is to employ temporary seals to isolate a small part of the mine and thus smother the fire, rather than to seal the entire mine. This procedure greatly simplifies the work and reduces the property loss. Fire and ventilation doors, where installed, speed up the work of sealing. At several fires mechanical ventilation under control greatly helped the fire fighters. Much of this work would be impossible without trained crews equipped to fight fires in gas and smoke. Without doubt many recent fires which resulted in insignificant losses would quickly have reached the disaster class had they started 20 years ago. Where some vital part of the fire protection had been neglected, some of the recent fires caused a considerable property loss.

The employment of fire-patrol men in the Lake Superior district is limited to a few companies, and has only recently been taken up. Three of the fires listed in the summary were discovered and extinguished by patrol-men. That such men could be employed to advantage at more properties is indicated by the fact that 29 out of the 55 fires either started or gained headway between regular working shifts. Many of the fires were detected by pumpmen or repair crews working in a distant part of the mine or by men on the surface; some were discovered only when the next shift went to work. A few of the fires had become serious before they were reached.

SPECIAL DANGERS

The great danger to life in most metal-mine fires is from fire gases -- particularly from carbon monoxide. There is always danger that workmen will be trapped by gas before they can be warned. Very few men have been injured directly by the fire, but carbon monoxide has caused the loss of many lives in remote parts of the mine. Where the ventilation is natural it is almost impossible to predict the course of the fire gases, and changes due to the progress of the fire or to local caves may occur at any minute.

To minimize danger there should be methods of quickly warning everyone in the mine; fire doors that divide the mine into as small sections as feasible should be installed; a plainly-marked second exit should be provided; and, in particularly hazardous places, a supply of self-rescuer type masks to protect the men while coming out should be available. Mechanical ventilation under control is of the greatest benefit in both rescue and fire-fighting work; where it is not used, crews unprotected by oxygen-breathing apparatus or All-Service gas masks should work cautiously, lest they be cut off from fresh air by an inflow of gas behind them.

FORMATION OF CARBON MONOXIDE

Carbon monoxide is usually defined as a product of incomplete combustion, since it is a combination of one atom each of carbon and oxygen. Much of the literature gives the impression that CO is formed mainly after a fire is sealed and deprived of the oxygen necessary for combustion. This is not necessarily true. The following facts on the formation of this gas are taken from a review of many articles:

CO may be distilled from wood by heat below the ignition temperature.

CO in dangerous quantities is produced by slow smouldering fires.

Normally, the hotter the fire the greater is the percentage of CO in the gases. CO has been formed so rapidly under such a condition that men have been overcome almost instantly in their working places.

Timber is approximately 50 per cent carbon, and this carbon is the source of most of the CO and CO_2 in the fire gases in metal mines. Computations of the ratio between these two gases produced by burning pure carbon at different temperatures were made by D. W. Rees (Coal Age, December, 1926). The results as shown in the graph accompanying his article are approximately:

Temperature, °F.	Parts CO_2	Parts CO
800	100	1
900	25	1
1,000	10	1
1,200	1	1
1,400	1	10

It can readily be seen that a hot, quick-burning fire is much more dangerous than a slower one. The higher the temperatures, also, the greater the expansion of the gases, and the more rapidly they will fill the mine workings.

All kinds of timber in the same physical state will ignite at about the same temperature. Experiments showed that on exposure to a temperature of 375°C. (657°F.), all specimens ignited in less than two minutes. The heat of an acetylene flame is given as 1,871°C. (3,400°F.), which is more than sufficient for essentially instant ignition. Quick-burning fires, especially in shafts or raises, produce intense heat. In one fire area that had been sealed, temperatures of 1,200° F. were recorded. At another place, copper ore was smelted.

The possibility of high carbon monoxide from a fire has been shown, but actual samples taken of the return air are usually below 1 per cent CO, and the writer has never found it above that figure at an unsealed metal-mine fire.

When a fire is first sealed, the oxygen content in the sealed area rapidly drops, and there is a rise in both CO and CO_2. Deprived of its oxygen, the fire slowly dies. Active combustion stops at about 16 per cent oxygen, and standing timber quickly cools below the ignition temperature. Timber that is buried under caves or piles of decaying timber, where the heat is not readily dissipated, will smoulder in air with a much lower O_2 content, ready to flare up on the admission of fresh air. As long as there is combustion, CO will form, and probably will continue to form in small quantities after active burning ceases, but as the fire cools, the CO decreases in concentration. Although it is not known just when or how this gas disappears, it is safe to say that as long as traces of CO are present behind fire seals, there is danger of a "flare-up" if air is admitted. The presence of CO has been used as an indicator of an active fire; experience has shown that this is a good danger signal.

BLACK SLATE OR SULPHUR FIRES

The occurrence of carbonaceous slate gives rise to a troublesome condition in a number of mines on the Menominee Range. The slate is structurally weak, apt to cave when exposed, and carries much finely-divided pyrite. When the slate is either crushed in place or caved into old workings, the air is admitted to a multitude of the small particles of pyrite. Oxidation goes on rather rapidly, and as the conditions are such that the heat of oxidation can not be dissipated, it finally reaches a temperature great enough to cause ignition of the pyrite and of the carbon of the slate. The resulting fires produce large quantities of SO_2 from the pyrite, and of CO and CO_2 from the carbon in the slate. On account of their location in old workings, these fires must usually be sealed tightly and kept sealed indefinitely. With

the admission of air, as long as there is exposed pyrite to oxidize, there will be a quick recurrence of fire. There is need for further study of these fires, especially of the gases produced by them. There is a possibility that small quantities of H_2S may be formed under certain conditions, as its characteristic order has been reported. The main thing noticed is the very low oxygen content behind the seals, making the use of oxygen breathing apparatus absolutely necessary if exploration or other work of any kind is to be done there.

In the prevention of these fires two things have been done successfully -- a protecting layer of ore has been left over the slate, and the stopes have been filled when completed. Filling of ignited stopes is also being tried. These measures have been successful, but their application to other mines is an economic problem. At least eight mines have experienced one or more of these fires. In each case the fires were bulkheaded by men in apparatus.

METHANE EXPLOSIONS

The occurrence of explosive gases in metal mines is rare enough to put the miners off their guard, but frequent enough to cause a number of accidents. In some metal mining districts, pockets of methane (CH_4) are found in carbonaceous formations. No gas-producing strata is known in the Lake Superior district. There have been a few fatal explosions of methane and a number of occurrences of it during the unwatering of old mines. There are two possible sources of methane common to the district which should be carefully considered when reopening a mine. The first is the decay of the mine timber in the absence of oxygen; this is probably the source of most of the occurrences. The other is the chance that waters coming into the workings through swamps or muskegs will trap the "marsh gas," or methane which is formed from the decaying vegetable matter in the swamp, and release it in the old workings.

The probability of finding methane is of sufficient importance to make necessary the careful and continuous testing of the air during unwatering and exploration. There are three appliances now approved for such testing; the flame safety lamp, the Burrell Methane Indicator, and the Martiensson Methane Indicator. Testing for explosive gases is part of the instruction given by the Bureau of Mines in its advanced fire-fighting course, and Car No. 8 is equipped with testing apparatus.

When methane is even suspected, all sources of ignition, such as open lights, open flame of any type such for instance as a lighted match, and sources of electrical arcs should be kept out of the mine until the air has been tested.

SPONTANEOUS IGNITIONS

Since burning is merely the rapid combination of atmospheric oxygen and the carbon, or other element, it is possible for a fire to start without the application of flame or external heat, merely through the rapid combination of these elements. Such fires are not common and can be guarded against. Two conditions are necessary: First, the opportunity for rapid oxidation; second, the retaining of the heat of oxidation. The materials which most readily oxidize are oils, greases, and the volatile hydrocarbons. Of this class of materials, oily waste or

rags, sawdust, or other finely-divided wood, are the most commonly found. If oily waste is so confined that heat from the oxidation of the oils can not be dissipated rapidly, spontaneous combustion is probable. The one recent fire in the district from spontaneous combustion originated in some oily waste that had been forced behind a post in a poorly ventilated pumproom.

Wood alternately wet and dried absorbs a much greater quantity of oxygen than it normally contains, and attains a condition where it is much more readily ignited than if kept either wet or dry. The more finely divided the wood is, the greater is the danger from this source. Such material does not have to be subjected to a high temperature to cause it to blaze; at just the proper stage, the sudden admission of air may cause sufficiently rapid oxidation to fire the mass. This is of importance where sawdust is used to pack steam lines.

Bacterial action in moist wood that is deprived of proper ventilation may create enough heat through fermentation to gradually char the wood. If oxygen in sufficient quantities is admitted, the mass may be raised to the point of ignition; this applies to sawdust or finely divided wood in old mine workings. The greatest danger from gob fires is found where human or animal excreta is present. Through the decomposition of this matter phosphorous compounds such as phospheretted hydrogen are formed and ignite upon contact with the air.

There is no record of a fire having started spontaneously in the caved top-slice rooms of the district. The highest temperatures that have been found in accessible spots are much below the danger zone. Nevertheless, it is only a reasonable precaution to exclude from the timber mat all materials that will increase the fire hazard.

FIRE-FIGHTING PLANS

Important steps in protecting a mine are to study it carefully, to face hazards honestly, and to formulate the best possible plans for meeting all emergencies. Such study may lead to the elimination of many dangerous conditions; it will show where fire protection is needed in the way of water, chemical extinguishers, and fire doors. Mapping of the regular air currents will help in planning the safe removal of men and the attack on the fire. Knowledge of the ventilation will also make possible the formulating of plans to be carried out on the discovery of a fire, the closing or opening of doors, and manipulation of fans, may save both life and property and greatly aid in fighting the fire. The first hour of a fire is the critical time, but there have been many mine fires where nothing was done until several hours had been consumed in confused planning. There are always many decisions that must be made for each fire. Where there is a general plan carefully thought out beforehand, these decisions can receive the undivided attention of the men in charge.

The tendency of many local mine officials to minimize the danger of underground fires is to be regretted. Their indifference causes them to neglect the making of fire plans, and also has an unfortunate effect upon the attitude of the

men. If the miners are led to believe that the mine is "fireproof" they will have little incentive to be careful in smoking or in the use of open lights. The bosses should frankly explain the dangers of the particular mine to the miners when instructing them as to the various exits to the surface, and should try to obtain their cooperation in preventing fire.

The need of previous organization and planning can only be mentioned here. A number of good papers have been written on the subject. One which covers it concisely and which is especially applicable to the Lake Superior district is "Fire Prevention and Fire Fighting in Metal Mines," by Eaton and Connibear. This paper can be found in the Proceedings of the Lake Superior Mining Institute for 1923 and is recommended to all who have not studied it.

FIRE-RESISTANT TIMBER

Experiments in making mining timber fire-resisting where steel, concrete, or masonry construction is not practical have proceeded along two lines. Coating timbers with gunite has been tried out extensively. The coating of cement makes the ignition of the timber from a local source of heat almost impossible, but experience has proved that it will not prevent the burning of the timber if subjected to a constant high heat. A recent fire started in an unprotected part of a shaft, below gunited timbers. The bare timbers were entirely burned out. The gunited timbers were burned to some extent for 300 feet above their lower limit, but the cement undoubtedly checked the fire. Only one or two sets of gunited station timbers nearest the shaft burned. The main objection that has been made to gunite is that the timber decays beneath it unobserved. Gunite is used quite extensively in the Lake Superior mines.

The treatment of timber with fire-resisting chemicals has been advocated, but the practice has been little used in the mines of the Lake Superior district. The burning of timber takes place in two ways: Volatile, combustible gases are driven off by the heat and burn, then the nonvolatile parts, such as charcoal, burn. To reduce the tendency to burn, three classes of chemicals can be used: Chemicals which are sublimated and give off noninflammable gases when heated and so dilute the inflammable ones; chemicals which lose their water of crystallization when heated and give off noninflammable gases; and chemicals which melt upon heating and form a nonburning protective coating in the wood. Laboratory tests of many chemicals have been made, so that their characteristics are known. None has been found which renders wood incapable of burning, but there are several that can be forced into timber so as to make it difficult to fire and much slower to burn. One of these, borax, has good fire-retarding properties and is an efficient fungicide, so that timbers treated with it are both fire and decay resistant. Experimental timbers treated with the different chemicals have been placed in the Athens Mine near Ishpeming, Mich. for service tests. If the timbers prove satisfactory, the use of the chemicals for treating mining timbers should become general.

RECENT FIRES IN OTHER DISTRICTS

Within the past six months there have been three metal-mine fires which caused heavy losses in lives and property. Two of the mines were not provided with mine-rescue equipment or men trained in the use of oxygen breathing apparatus. At the third mine there was only enough equipment for one crew. Much valuable time was lost because no previous organization scheme had been thought out beforehand. In each case the fire hazard had been greatly underestimated by the men in charge. The habit of failing to recognize the serious possibilities of familiar conditions in the mine is too common in all metal-mining districts. The fireproof mine is a rare exception -- in fact, is almost nonexistent.

The results of the study of mine fires in various parts of the country can be found in the following Bureau of Mines publications: Bulletin 188, Lessons from the Granite Mountain Fire; Technical Paper 24, Mine Fires, a Preliminary Study; Technical Paper 314, Metal-Mine Fires; and Bulletin 229, Fifty-Nine Coal-Mine Fires.

RESULTS OF MINE FIRES

The results of mine fire are often more serious than appear at a casual glance. The direct costs of fighting the fire and reclaiming the mine are high. Once a fire gets beyond direct control, the expense mounts rapidly. Such a fire in a drift seldom costs less than $10,000 and frequently exceeds $50,000. Fires in timbered shafts cost more and are more apt to disrupt production for long periods; they seldom cost less than $50,000, and a few have reached the million-dollar class. Even though there is no loss of life, the expense of reopening the burned area is a serious thing for the company. The employees and the community suffer generally through the enforced unemployment of a large part of the men.

Serious loss of life at mine fires always results in undesirable publicity, political investigations, and attempts at regulatory laws, and strained relations with the workmen, affecting not only the mine which suffers the loss, but the entire industry in the section and state. For these reasons every effort should be made to promote among both mine operators and miners a sentiment that would deter any company from operating under conditions permitting of disaster.

SUMMARY

The circumstances attending fires which have recently occurred compel the conclusion that the mines of the district contain serious fire hazards. However, much good fire-prevention work has been done, the results of which are seen in the decrease in fires in shafts and stations through fireproofing. The tendency in new construction is toward fireproof structures. Some mines have done practically all that is possible in the way of providing fire-fighting equipment, trained men, building fire doors, installing stench warnings, keeping the mine clean, and formulating fire-fighting plans. The protected class of mines is becoming larger each year, but there are still a few which are unprotected and have grave fire hazards.

The results obtained by the trained fire-fighting crews called upon to use oxygen breathing apparatus have been very gratifying and have greatly reduced property losses. The district generally is well provided with apparatus and men. Recent loss of life has been very small.

Electricity has been shown to be by far the most frequent cause of ignition. The common belief that a trolley circuit will not start a fire has been disproved. The number of mine fires in which every type of electrical equipment has been involved as a cause, demonstrates the need of carefully installing and inspecting electrical equipment.

The number of fires which have started between regular working shifts shows the value of fire patrols during the time when no work is being done.

A survey of fire hazards and a detailed plan of fire fighting in each mine is recommended.

Probably the most essential factor in the handling of a mine fire is mechanical control of ventilation; hence every mine, metal as well as coal, should have a mechanically operated fan and a well systematized coursing and control of air currents.

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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

HOW FIRES START IN MINES[1, 2]

By K. L. Marshall[3]

Of all the hazards faced by men engaged in mining, an underground fire inspires the greatest dread. For lengthy periods a mine fire holds the threat of imminent disaster, even when such a disaster does not occur.

No available figures give the total number of mine fires that occur annually in the United States, nor are there figures showing the cost of property damaged by such fires. If such figures were compiled, it is believed that they would be staggering, even to men well informed in mining.

The bureau's statistics on fires are limited to those that have led to loss of life and to disasters. These statistics show that over 25 men are killed annuall by mine fires or by explosions originating from fires in coal mines, and that from 1917 to 1926, 229 men were killed by fires in metal mines. Moreover, the Bureau of Mines has assisted at 69 fires in the past five years. The 69 fires include only those of a considerable magnitude and do not take into account the hundreds of small fires which are quickly extinguished and which in many mining districts are a common and almost daily occurrence.

For convenience and clearness, causes of fires in mines will be discussed under two general heads: First, foreign heat ignitions, and second, spontaneous ignitions. All fires caused by flames, heat, or electricity brought by men or appliances into the mine in the course of operation may be classified as foreign ignitions. Fires due to spontaneous combustion will be discussed in conjunction with spontaneous ignitions; the source of such combustion is not limited to the material originally in the mine, but applies as well to combustible material taken into the mine.

Foreign heat ignitions are brought about in numerous ways. The order in which these ignitions are discussed will be that of the frequency of their probable occurrence, although without complete statistics available the relative seriousness is subject to question.

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1 The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"

2 Presented at the regional meeting of the National Safety Council at Kansas City, Mo., April 25, 1928.

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In mines of all classes the open flames of miners' lamps, underground forges and fires for thawing frozen air lines and water lines have been consistent agents in starting mine fires. Such flames have had the able assistance of gas feeders, accumulated trash, oily rags and waste, dry timbers or lagging, oil, and gasoline as the easily kindled media that supply heat to extend the fire into timbering and the material mined; the latter includes not only coal but also several combustible ores.

Fires of electrical origin now undoubtedly rank second in the list. Electric currents and electrical equipment of almost every type have been the cause of fires. The electric wired circuits, however, are probably the most frequent igniting agents.

Electric currents in a number of ways produce enough heat to ignite inflammable material. The first and most evident producer of heat is the electric arc, the flame of which has a very high heat intensity and is dangerous under some conditions of mining at almost any voltage and amperage. Arcs are produced at all "make-and-break" contacts in air. These "makes" and "breaks" may occur in the course of operating switches, commutators, trolley wheels, or controllers during normal duty; or they may be unintentionally produced by defective circuits, such as loose and poorly made connections, partial short circuits on exposed wires, or broken bonds on track. Arcing at bonds on mine haulage-tracks is frequently overlooked, especially when fine, as well as large-size, coal spilled from cars has accumulated about the bonds. Under such a condition a fire is almost inevitable, and is extremely difficult to control as there is usually a strong current of air in the haulageways.

Resistance to the passage of electricity through any conducting medium produces heat. Such heating can be closely compared to the heat of friction in ordinary mechanics. Under many conditions heating by passage of electric current can produce a temperature high enough to ignite any inflammable material that may be in contact with the electrical conductor. Insulation of circuits or machine windings on heavy overload may ignite from such heat, or fires may be started in inflammable material adjacent to overheated circuits or machines; fires may also be started by the passage of current through high-resistance material (such as canvas, posts, or timbers) in contact with electric circuits not normally overloaded. Ignition is more likely to take place when the material in contact with the circuit is damp.

Heat of resistance is used to produce the glowing filament of incandescent lamps, and there must be heat, otherwise there would not be light. Incandescent bulbs can and do light inflammable material if kept in contact long enough; hence the use of cardboard, paper, or other combustible as a shade for electric lamps should be discouraged, and electric light bulbs should not be allowed to touch timber caps, legs, or lagging.

Heat is produced in the normal use of resistors or "grids" in connection with speed control and starting equipment of electric motors. Grids have started fires when improperly installed and maintained. The surrounding surfaces should be well fireproofed in places where grids are used on stationary electrical equipment

Fires have been reported even in modern, underground storage-battery charging stations. This is serious, since hydrogen gas may be present to convert slight arcing into a fire of large proportions, or even to cause an explosion.

Lightning has been known to go underground on power circuits. There is no reason why fires can not be started in mine workings in the same way as in surface buildings, which frequently fire when struck by lightning; hence there should be provision against entrance of current from lightning into mine wiring.

Stray currents complete the list of electrical sources of fires. There is a record of a stray current which was of sufficient intensity to heat certain members of a steel headframe and tipple and thus cause a fire on the tipple. This is an isolated case, but such an origin may well be given thought before a fire is placed in the "cause undetermined" class. A prominent coal-mining engineer recently said that at least 90 per cent of the present-day "mysterious" fires in coal mines are of electrical origin.

Explosives occupy the third place on the list of ignition agents in mine fires. Long-flame explosives have caused hundreds of mine fires; but for the continued growth of the use of permissible explosives, long-flame explosives such as dynamite and black blasting powder would be first on the list.

In many districts where black blasting powder and dynamite are still used in coal mining, "fire runners" are employed to search for fires after shooting. These men are required to extinguish fires started by blasting with these explosives. This type of precautionary service is decidedly valuable. Where work has been intermittent, many such fires have reached serious proportions during the idle days; not only have they caused much trouble, but in some instances have also resulted in explosions. Explosives and fuse have also served as media to aid the relatively low heat of a glowing match stem or cigarette butt to start many large and serious fires.

To complete the "foreign heat ignitions" and act as a connecting link with "spontaneous ignitons," there are several important but rare causes of fires:

The frictional heat of machine bearings has caused fires which probably start in the oil and grease accumulations on the machine itself and spread to inflammable material in the vicinity. Pumps, underground fans, and similar machinery, which often run for long periods with little attention, are the most probable sources of fire from frictional heat. Rollers on rope haulage and friction of rope on timbers have caused fires; a recent serious metal-mine fire is ascribed to the latter cause.

Steam lines have been charged with starting mine fires; although the accuracy of this charge may be questioned, nevertheless the heat radiated by lines carrying steam and hot water would no doubt greatly assist in accelerating "spontaneous ignition" in coal dust, trash, oily clothes, or similar highly inflammable material that might be nearby.

The causes of "spontaneous ignitions," -- the second main class of mine fires -- should be fully understood by the entire mining fraternity, even though this cause varies decidedly in frequency and seriousness among the various mining districts of the United States.

Any extraneous inflammable material that is known to fire spontaneously on the surface can be expected to fire spontaneously, under favorable conditions, when taken underground. Oily material and "trash" are especially likely to ignite spontaneously. Timber stored or in place is not commonly thought subject to spontaneous ignition, but care must be taken that such storage be kept free from even small amounts of finely divided bark, splintered wood, oily waste, or any material that could furnish a small point of firing whence the flame might spread quickly to large proportions. Spontaneous fires have occurred in accumulated piles of wood splinters or bark at the foot of timber slides in metal mines.

Sulphide ores, especially of copper and iron, are known to fire spontaneously when aided by the heat of crushing.

There are not enough data available to permit classification of any given coal as free from all possibility of spontaneous ignition under every condition. However, many coals are known to be prone to spontaneous combustion and require continuous vigilance, care, and even special mining methods to make their recovery possible with reasonable safety. Spontaneous fires are seldom accompanied by fatalities; the time required in the heating process usually gives opportunity for detection, so that steps to avoid fatalities can be taken. These fires, however, have cost much time, effort, and money and have taken a great toll in property and equipment.

Fires have sometimes gone underground, although started in surface buildings near shafts or other openings. Such fires are liable to occur at any time when headframes, tipples, hoist houses, and other constructions are not fireproof.

Fires in outcrops, some of untold years' standing, have been cut into and have spread through the active mine workings. Care should be exercised not to locate rock dumps, which are likely to burn, over outcrops; nor should rock dumps be located above mine areas that might cave to the surface and allow the hot dump material to reach the underground workings. It is recorded that a coal vein was completely burned at 1,800 feet from the outcrop and under several hundred feet of cover. If there is any indication of "crop" fire ever having occurred, careful study should be made to determine whether the fire might still be active, and the limits should be accurately mapped.

Veins of coal have been burned and coked by intrusive molten dykes. Few if any such fires have been found active, but there is no reason why it would not be possible to have heating conditions near underground dykes that might start fires.

To give examples of fires started by all the media discussed is not feasible in a paper of this kind, nor will an attempt be made to suggest all of the preventive measures that have been and should be used to reduce the opportunity for such occurrences. Most of the answers to the problems of fire prevention are self evident. However, it may be well for every operator to request of his organization a concrete and effective answer to the question "How to Prevent Fires in our Mines."

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Circular No. 6082
September, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

SAFEGUARDING ELECTRICAL EQUIPMENT USED IN GASSY MINES[1]

EUROPEAN PRACTICE: I - GREAT BRITAIN

By L. C. Ilsley[2]

INTRODUCTION

Cooperation between the United States Bureau of Mines and the Safety in Mines Research Board of Great Britain, continuous since 1924, has made possible this and other papers on safety subjects. Grateful acknowledgment is made to representatives of the Safety in Mines Research Board of the Mines Department for their assistance in arranging visits to several mine safety stations, and to F. H. Wynne, Deputy, Chief Inspector of Mines, Great Britain, for arranging visits to mines in Great Britain, Belgium, France, and Germany.

During the summer of 1927 the writer had the privilege of visiting the mine safety testing stations in Great Britain, Belgium, Germany, and France, in the order named. All of these countries have large coal mines, many of which are rated as gassy. Therefore, when the installation of electrical equipment is contemplated, each of these countries is confronted with the same safety problem as in the United States - the development of electrical equipment that will not ignite gassy mine atmospheres, should such atmospheres through neglect or accident surround the equipment. The means used by those countries in safeguarding gassy mines should therefore be of general interest to safety engineers in American coal mines, and it is proposed to give a brief survey for each of the four countries mentioned. The first of these surveys will cover conditions in Great Britain.

REGULATION BEARING ON SAFETY

A good beginning may be made by mentioning some of the requirements found in "Coal Mines Act, 1911." This act includes a section, "General Regulations As to the Installation and Use of Electricity," from which the following pertinent paragraphs have been abstracted:

1 - The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)
2 - Electrical engineer, U. S. Bureau of Mines.

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(119.) Notices shall be sent to the Inspector of the Division, on the forms prescribed by the Board of Trade, as follows, namely:

(119.)--(i.) Notice of the intention to introduce apparatus into any mine, or into any ventilating district in any mine.

If the Inspector of the Division does not object in writing, within one calendar month from the receipt by him of the notice, to the carrying out of either of the intentions specified in the first or second notices, the owner shall be entitlted to carry out such intention or intentions.

Provided that this regulation shall not apply to telephones and signalling apparatus.

(119.)--(ii.) Notice of the intention to introduce or reintroduce electrocity into any mine where the use of electricity has previously been prohibited by Section 60 (1) of the Act.

If the Inspector of the Division does not object in writing, within one calendar month from the receipt by him of the notice, to the carrying out of either of the intentions specified in the first or second notices, the owner shall be entitled to carry out such intention or intentions.

Provided that this regulation shall not apply to telephones and signalling apparatus.

(119.)--(iii.) On or before the 21st day of January in every year an annual return giving the size and type of appratus and any particulars which may be required by the Board of Trade as to the circumstances of its use.

(125.)--(a.) All metallic sheaths, coverings, handles, joint-boxes, switchgear frames, instrument covers, switch and fuse covers and boxes, and all lampholders, unless efficiently protected by an earthed or insulating covering made of fire-resisting material, and the frames and bedplates of generators, transformers, and motors (including portable motors), shall be earthed by connection to an earthing system at the surface of the mine.

This rule shall not apply (except in the case of portable apparatus) to any system in which the pressure does not exceed low-pressure direct current or 125 volts alternating current.

(125.)--(b.) Where the cables are provided with a metallic covering constructed and installed in accordance with Regulation 129 (e) such metallic covering may be used as a means of connection to the earthing system. All the conductors of an earthing system shall have a conductivity at all parts and at all joints at least equal to 50 per cent of that of the largest conductor used solely to supply the apparatus a part of which it is desired to earth. Provided that no conductor of an eathing system shall have a cross-sectional area of less than 0.022 of a square inch.

(125.)--(c.) All joints in earth conductors and all joints to the metallic covering of the cables shall be properly soldered or otherwise efficiently made, and every earth conductor shall be soldered into a lug for each of its terminal connections. No switch, fuse, or circuit breaker shall be placed in any earth conductor.

(131.)--(a.) Every person appointed to work, supervise, examine, or adjust any apparatus shall be competent for the work that he is set to do. No person except an electrician or a competent person acting under his supervision shall undertake any work where technical knowledge or experience is required in order adequately to avoid danger.

(131.)--(b.) An electrician shall be appointed in writing by the manager to supervise the apparatus. If necessary for the proper fulfillment of the duties detailed in the succeeding paragraphs of this rule, the manager shall also appoint in writing an assistant or assistants to the electrician.

(131.)--(c.) The electrician shall be in daily attendance at the mine. He shall be responsible for the fulfillment of the following duties, which shall be carried out by him or by an assistant or assistants duly appointed under paragraph (b) : (i.) the thorough examination of all apparatus (including the testing of earth conductors and metallic coverings for continuity) as often as may be necessary to prevent danger; and (ii) the examination and testing of all new apparatus, and of all apparatus reerected in a new position in the mine before it is put into service in the new position.

Provided that in the absence of the electrician for more than one day the manager shall appoint in writing an efficient substitute.

(131.)--(d.) The electrician shall keep at the mine a log book made up of daily log sheets kept in the form prescribed by the Secretary of State. The said log book shall be produced at any time to an inspector of mines on his request.

(131.)--(e.) Should there be a fault in any circuit the part affected shall be made dead without delay, and shall remain so until the fault has been remedied.

(131.)--(f.) All apparatus shall be kept clear of obstruction and free from dust, dirt, and moisture, as may be necessary to prevent danger.

Inflammable or explosive material shall not be stored in any room, compartment, or box containing apparatus, or in the vicinity of apparatus.

(131.)--(g.) Adequate precautions shall be taken by earthing or other suitable means to discharge electrically any conductor or apparatus, or any adjacent apparatus if there is danger therefrom, before it is handled, and to prevent any conductor or apparatus from being accidentally or inadvertently electrically charged when persons are working thereon. While lamps are being changed the pressure shall be cut off.

Provided that this paragraph shall not apply to the cleaning of commutators and slip rings working at low or medium pressures.

(131.)--(h.) The person authorized to work an electrically-driven coal-cutter or other portable machine shall not leave the machine while it is working, and shall, before leaving the working place, ensure that the pressure is cut off from the flexible trailing cable which supplies such coal-cutter or other portable machine. Trailing cables shall not be dragged along by the machine when working.

(131.)--(i.) Every flexible cable shall be examined periodically (if used with a portable machine, at least once in each shift by the person authorized to work the machine), and if found damaged or defective it shall forthwith be replaced by a spare cable in good and substantial repair. Such damaged or defective cable shall not be further used underground until after it has been sent to the surface and there properly repaired.

(132.) In any part of a mine in which inflammable gas, although not normally present, is likely to occur in quantity sufficient to be indicative of danger, the following additional requirements shall be observed:-

(132.)--(i.) All cables, apparatus, signalling wires, and signalling instruments, shall be constructed, installed, protected, worked, and maintained, so that in the normal working thereof there shall be no risk of open sparking.

(132.)--(ii.) All motors shall be constructed so that when any part is live all rubbing contacts (such as commutators and slip-rings) are so arranged or enclosed as to prevent open sparking.

(132.)--(iii.) The pressure shall be switched off apparatus forthwith if open sparking occurs, and during the whole time that examination or adjustment disclosing parts liable to open sparking is being made. The pressure shall not be switched on again until the apparatus has been examined by the electrician or one of his duly appointed assistants, and the defect (if any) has been remedied or the adjustment made.

Some of the outstanding features of the rules just quoted that have a chief bearing in maintaining electrical safety are:

1. Strict rules with respect to giving notice to the Mines Department of intention of installing new equipment.

2. Strict rules regarding the earthing (grounding) of all equipment and wiring.

3. Instructions for selection of the electrician and other workmen with the requirement that the electrician must be in constant attendance.

4. Requirement that a daily log must be kept of happenings on electrical apparatus in a prescribed log book.

5. Requirement that defective equipment be put out of service at once.

6. Special rules covering the use of electrical equipment and wiring in gassy portions of the mine to prevent "open sparking."

TESTS AND REQUIREMENTS FOR ELECTRIC MOTORS

The users and manufacturers of electrical equipment are taking forward steps to formulate testing procedure for equipment and to meet the expense entailed in having types of equipment tested.

The following regulation approved and issued in 1926 under the auspices of the British Engineering Standards Association (composed of the Institution of Civil Engineers, Institution of Mechanical Engineers, Institution of Naval Architects, Iron and Steel Institute, and Institution of Electrical Engineers) shows the general trend of testing electrical equipment for safety in Great Britain:

British Standard Specifications for Flame-Proof Enclosures and for Testing Such Enclosures

I. Definition of Flame-Proof Enclosure (Including Explosion-Proof) for Electrical Apparatus.

1. A flame-proof enclosure (including explosions-proof) for electrical apparatus is one which will withstand, without injury, any explosion that may occur in practice within it under the conditions of operation within the rating of the apparatus enclosed by it (and recognised overloads, if any, associated therewith), and will prevent the transmission of flame such as will ignite any inflammable mixture which may be present in the surrounding atmosphere.

Note 1.--In the absence of any statement to the contrary, it is assumed that the flame-proof enclosure has to meet the ordinary requirements of the Coal Mining Industry in which the inflammable mixture to be considered will ordinarily contain methane, but in other industries other inflammable mixtures will be encountered. Similarly it will be necessary to consider other inflammable gases in relation to particular apparatus, such as the gas resulting from decomposed oil in oil-immersed switchgear and hydrogen in storage batteries.

Note 2.--In view of the danger which would result from a destructive short-circuit within the enclosure, special attention to details of deisgn and manufacture is necessary. In addition, the protection of the circuit supplying the apparatus should be such as to ensure, as far as practicable, that the highest recognised overload for the apparatus shall not be exceeded, having regard to the amount of destructive energy available at the apparatus calculated from the size of generating plant and the impedance of the circuit between it and the apparatus.

II. Specification of Tests for Various Classes of Apparatus to Prove Compliance with the Definition of Flame-Proof Enclosure.

General

2. In conformity with Note 1 to the Definition of Flame-Proof Enclosure, it is assumed that the apparatus has to meet the ordinary requirements of the Coal Mining Industry in which the inflammable mixture to be considered will ordinarily contain methane.

For some purposes a certificate may be required as to the flame-proof qualities of a casing with respect to such inflammable mixtures as, for example, hydrogen and air. Such a certificate shall be granted only on the results of tests carried out with the particular inflammable gas specified therein.

The design and construction of flame-proof apparatus submitted for test and certificate should comply, as regards flame-proof enclosure, with the B.E.S.A. Specification, if any exists, for such apparatus, but if there is no such Specification then the principles of design and construction, as regards flame-proof enclosure, in any appropriate B.E.S.A. Specification should be observed.

Tests

3. The following tests shall be carried out with the apparatus correctly assembled, with all its parts (including oil, filling compounds, etc., if any) in place, and with all electrical connections from the interior to the exterior of the casing made. Apparatus designed for the protection of rapidly revolving parts, such as a motor casing, shall be tested with such parts running at their maximum working speed.

To meet the ordinary requirements of the coal mining industry, the casing shall be filled at the air temperature and pressure prevailing at the testing station with the most explosive mixture of methane and air (i.e., containing between 9.5 and 10.5 per cent of methane by volume) and shall be surrounded by the most readily ignited mixture of methane and air (i.e., containing between 8.5 and

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10.5 per cent of methane by volume) at the air temperature and pressure prevailing at the testing station. The tests of flame-proof enclosures in any other inflammable atmosphere than that containing fire damp shall be made with the most explosive mixture of the particular inflammable gas and air at the temperature and pressure prevailing at the testing station. The explosive mixture within the casing shall be ignited, if possible, by the spark produced when an electric current of sufficient intensity is established or broken by the normal mechanical operation of the apparatus. Otherwise, any suitable means may be employed provided that the position of the point of ignition would be produced in the normal working of the apparatus.

It is recognised that until such time as experimental work on the testing of switchgear under short circuit conditions has been completed, it would be unwise to specify that the enclosure should be tested for its flame-proof properties with the apparatus operating under the most severe conditions likely to be met in normal service. The tests specified, therefore, are liable to revision and modification after further research if it is found that testing under short-circuit conditions is essential.

Note:--It is not considered desirable to define the number of tests or the character of any additional tests which the testing officer might desire to make. It is hoped that further instructions can be given after experience has been gained.

Test Certificate

4. An apparatus that satisfies the requirements of this Specification and has passed the tests to which it has been submitted can be considered as complying with the British Standard definition of Flame-Proof Enclosure and a certificate in the form given in Clause 5 should be granted.

Form of Test Certificate

5. The following form of test certificate should be used:---

Certificate of Test as to Flame-proof Enclosure. This is to certify that a .... (description of article), identical in all essential respects as to design, workmanship and material with that indicated on Drawing No. .... has been submitted by .... (Name of Maker) for test to prove compliance with the definition of flame-proof enclosure (B.E.S.A. Publication No. 229--1926.) and has been found to satisfy the requirements in all respects.

A full report of the tests carried out has been furnished to the maker.

Signed..................(testing authority).

Date................

Type Tests

6. It is not intended, nor is it recommended, that the tests referred to above shall be made on every piece of apparatus supplied.

Unless otherwise specified when inviting tenders, the purchaser shall accept, as evidence of compliance of the apparatus with this Specification, type tests on apparatus identical in all essential details with the one purchased.

Certificates and full report of all type tests with certified detailed drawings of the type apparatus shall be held available by the maker, together with a record of any alterations, whether essential or not, which have been made to the apparatus since any type test was carried out.

Type tests shall be made by a recognised authority.

Twenty-five Government Departments and Scientific and Industrial Organisations were officially represented upon the Committees entrusted with the preparation of the Specification.

TESTING OF FLAME-PROOF EQUIPMENT

Although the Mines Department tests flame safety lamps, electric lamps, signals, telephones, and shot-firing equipment, it does not test electric motors and their accessories. Such tests as are made are either conducted by the manufacturers of the equipment or are arranged for by them.

The University of Sheffield has an agreement with the manufacturers whereby tests are made of flame-proof equipment at Sheffield. These tests, although generally witnessed by an engineer from the Mines Department, can not be said to be officially endorsed by that department. Equipment that satisfies the conditions laid down for the tests is given a certificate by the University.

The writer witnessed some of the testing work at Sheffield and was deeply interested in it because similar testing work was being done at the Pittsburgh Experiment Station of the U. S. Bureau of Mines.

The test procedure at Sheffield is as follows:

The submittor of the equipment is required to furnish blue-print copies of drawings showing the general construction of the apparatus submitted. These prints are consulted in deciding whether or not the construction of the apparatus is satisfactory and are further used in checking the dimensions of the various parts making up the equipment. Prints are held on file as a part of the permanent record of the test.

The tests are made in a wooden gallery. The gas used for the explosive mixture is methane, which is obtained from a mine and kept in cylinders. An explosive mixture is kept ready mixed in a large container for certain of the tests. In the case of a motor the first test is made by filling the motor with an explosive mixture of methane and igniting the mixture. During this test one end of the gallery is open. This test is made without an explosive mixture surrounding the motor and is for the purpose of observing whether flames come through any of the flanges or the other joints. After the completion of this test, the front of the gallery is put in place and five additional tests are made with the motor surrounded with an explosive mixture of methane and air. Two of the tests are with the motor at rest and three tests with the motor running. Owing to the construction of the gallery the motor is not under observation in any of the tests in which the motor is surrounded by the explosive mixture. The evidence of safety is therefore based upon the one test made at the beginning under observation and the fact that in the additional five tests the gas was not exploded or the compartment blown apart. Pressure records and analyses of gas samples are obtained for all the explosion tests. The proper proportion of the mixture surrounding the motor is judged by exploding samples drawn from the gallery during the mixing of the methane and air. The methane is slowly admitted from one of the tanks and mixed with a fan as it enters.

The gallery is provided with a partition to conserve the amount of gas necessary for producing an explosive mixture. If the apparatus is small enough it is installed in a half section of the gallery.

A typical certificate follows:

University of Sheffield

MINING DEPARTMENT,

UNIVERSITY OF SHEFFIELD,

(SEAL)

ST GEORGE'S SQUARE,

SHEFFIELD

Telephone 4705

October 15th., 1923.

Certificate No. 40.

This is to certify that a typical example of MESSRS. THE ELECTRO-MECHANICAL BRAKE COMPANY, LIMITED, MINING TYPE FLAME PROOF CONTROLLER TYPE 50A., 30. FP., has been treated as follows:-

> The casing of the controller was filled with the most explosive mixture of fire damp and air, and this mixture was ignited by a secondary discharge from an induction coil, whilst the apparatus assembled as for use was surrounded by a similar explosive mixture.

Under these conditions of test, flame did not pass from the apparatus to the explosive atmosphere outside, which remained unignited, nor did the apparatus suffer damage due to the pressure developed within it.

Signed: D. Hay

Professor of Mining.

When one considers the rigid regulations covering electrical equipment in British mines, it would be natural to think that the protective requirements for gassy parts of a mine would be especially severe, but this is not necessarily the case. Much of the equipment used at the face workings has not been tested at Sheffield. The tendency apparently is to place more emphasis on inspection than on actual tests in gaseous mixtures. The Bureau of Mines has found in testing a great many outfits representing the product of several manufacturers that tests are very valuable in showing unsuspected weaknesses of equipment which might easily be overlooked or not evident from an inspection.

RESEARCH WORK BY THE SAFETY IN MINES RESEARCH BOARD

During a period of several years a systematic study has been made by the Safety in Mines Research Board, under R. V. Wheeler, of fundamentals that may have a direct or indirect bearing on the design of permissible electrical accessories for motor-operated outfits; the following reports have been issued:

1. Flame-Proof Electrical Apparatus for use in Coal Mines, by I. C. E. Statham and R. V. Wheeler, Paper No. 5, First Report, Flange Protection, 1924.

2. Flame-Proof Electrical Apparatus for use in Coal Mines, by C. S. W. Grice, and R. V. Wheeler, Paper No. 21, Second Report, Perforated Protection, 1926.

3. Flame-Proof Electrical Apparatus for Use in Coal Mines, by H. Rainsford and R. V. Wheeler, Paper No. 35, Third Report, Ring-Relief Protection, 1927.

4. The Pressures Produced on Blowing Electric Fuses, by G. Allsop and R. V. Wheeler, Paper No. 38, 1927.

The writer saw most of the equipment used in conducting these researches and conferred with several of the investigators who had been connected with the work. It may be mentioned here that these researches cover work for which the United States Bureau of Mines has never had sufficient personnel, and as the work has been done in a thorough manner it will probably never be necessary for the Bureau to undertake it.

ELECTRICAL INSPECTION

The electrical inspection work in Great Britain is in the hands of the Divisional, Assistant, and Junior Mine Inspectors; in case of an electrical accident or a difficult electrical problem, these men call on the Chief Electrical Inspector, who has his headquarters at the Main Office of the Mines Department.

The inspection of electrical equipment is made comparatively easy by the rigid rules (samples of which have already been given) governing the installation of new equipments and the maintenance requirements for all electrical equipment.

There is only one electrical inspector, and as his is a huge task it is impossible to avoid some mistakes and misjudgments in permitting installations. Greater safety would undoubtedly result if more electrical equipment was subjected to actual tests in gas.

In addition to the Government inspection, many of the owners carry out very complete and systematic periodic inspections. One company with four collieries had a force of 16 electricians and a most elaborate inspection system.

ELECTRICAL EQUIPMENTS IN GREAT BRITAIN AND THE UNITED STATES CONTRASTED

There are a number of differences between the electrical installations in Great Britain and the United States. For instance, in British coal mines there are no trolley locomotives, whereas statistics compiled for 1924 give 11,986 in the United States. Every piece of apparatus and practically every conductor in British mines is earthed by carrying a ground conductor to a ground plate on the surface; practically no earthing is resorted to in American mines except to connect the frames of stationary motors to a pipe or rail return within the mine. Alternating current is not used extensively in American mines, but in British mines this prevails, and direct-current circuits are being replaced by alternating-current circuits in a number of mines. The natural conditions in British mines as to grades, faults, thinness of seams, extreme depth of shafts, and the difficulty of properly supporting the overburden render the installation of electrical equipment much more difficult than in American mines.

In regard to electrical safety it can be said without danger of contradiction that the regulations governing the installation, inspection, and maintenance of electrical equipment are better in Great Britain than in America. In regard to the practice of using strictly safe equipment in gassy sections of mines, there is much yet to be done in both countries.

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Circular No. 6083
September 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

ARE FLAME SAFETY LAMPS SUITABLE FOR DETECTING PETROLEUM VAPORS?[1]

By A. B. Hooker,[2] W. P. Yant,[3] and D. H. Zellers.[4]

PURPOSE OF INVESTIGATION

Before repairs are made on storage-tanks that have contained crude oil, gasoline, or other distillates of petroleum, it is advisable to be sure that a minimum amount of vapor is present. The examination for vapor should be thorough; it should be made immediately before the tank is entered by the repairmen and periodically thereafter until the men have left the tank.

The flame safety lamp has been suggested as suitable for this service and has been used to some extent by at least one company. In response to inquiries, an investigation was made at the Pittsburgh Experiment Station to determine whether it is safe to use the miner's permissible-type flame safety[5] lamp in gasoline vapors, and their suitability in general for such use.

CONCLUSIONS

The investigation reveals that while permissible miner's flame safety lamps when correctly assembled and intact will not ignite mixtures of gasoline vapor and air, these lamps are not suitable for determination of inflammable vapor content of the atmospheres in and around tanks. The lamps will give unmistakable evidence of the presence of an explosive mixture and will give satisfactory indications to a trained observer in vapor percentages of approximately half of the lower explosive limit. Below this limit the lamps decrease in value as detectors, and at 0.3 percent and lower the evidence is so small and difficult to observe that it should not be depended upon.

1/ The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"
2/ Associate electrical engineer, Pittsburgh Experiment Station.
3/ Supervising chemist, health laboratory section, Pittsburgh Experiment Station.
4/ Assistant electrical engineering aide, Pittsburgh Experiment Station.
5/ Paul, J. W., Ilsley, L. C., and Gleim, E. J., Flame Safety Lamps: Bull. 227, Bureau of Mines, 1924, 212 pp.; Paul, J. W., The Use and Care of Miners' Flame Safety Lamps: Miners' Circular 12, Bureau of Mines, 1913, 16 pp.; Ilsley, L. C., Misuse of Flame Safety Lamps and Dangers of Mixed Lights: Miners' Circular 29, Bureau of Mines, 1925, 12 pp.; Ilsley, L. C., Inspection and Assembly of Flame Safety Lamps at the Mine: Reports of Investigations, Serial 2302, Bureau of Mines, 1921, 3 pp.

Safe practice requires that repairmen do not enter a tank if any trace of gas is present, and since the tests show that the flame safety lamp cannot be depended on to give evidence of gas percentages below about 0.3 percent (and not then except in the hands of one experienced in handling the lamp), it is manifest that the flame safety lamp is not suitable for testing for small percentages of these gases. The proper and efficient detection of petroleum vapors in and around tanks would seem to require a detector that is more accurate and more readily observed than a flame safety lamp. There should be a rugged and portable device especially designed for such use, which would give direct indications at once, and which would be readily visible when readings are being taken at the bottom of a tank. It is believed that such detectors will soon be available to the petroleum industry.

CHARACTER OF TESTS AND GASOLINE USED

The investigation included three series of tests as follows:

1. Safety tests in explosive mixtures moving at approximately 2,500 feet per minute.

2. Safety tests in still and low-velocity explosive mixtures in which the temperatures of the lamp gauzes were measured by means of thermocouples.

3. Tests to determine the behavior of wick flames in various percentages of vapor.

Casing-head, or natural gasoline composed of butane, pentane, and hexane, with pentane predominating, was used.

1. Safety Tests in Moving Mixtures

The tests in moving mixtures were made in the bureau's regular gallery for testing flame lamps. The gasoline was vaporized in a special vaporizer made of a 4-foot length of 8-inch iron pipe with flanged ends. It had valves and pipe connections for mixing steam and the gasoline in proper amounts as they entered the vaporizer, also a series of internal chambers and baffles to separate the condensate from the vapor and allow of its removal.

The velocity of the vapor-air mixture was determined by the amount of air flowing through the test gallery. The mixtures were made by trial and the percentages determined by means of a thermal-conductivity type of gas-analysis apparatus, which on a few occasions was checked by combustion analysis.

A representative lamp of each of the Koehler and Wolf permissible types was used. The tests were made in explosive mixtures of vapor and air and in velocities of approximately 2,500 feet per minute past the lamp. In some of the tests the mixture moved horizontally past the suspended lamp; in others it moved obliquely (45°) down past the suspended lamp; and in others the lighted lamp was thrust up into the horizontally moving mixture. The duration of the tests varied from one to seven and a half minutes, with an average of about two minutes.

Test Results

These tests, based upon previous tests in methane and air mixtures, were chosen as giving the conditions for maximum burning within the lamps and therefore the greatest heating of the gauzes. Although the inner gauze was perceptibly heated in each test, no ignitions were obtained.

2. Safety Tests in Still and Low-Velocity Mixtures

The tests in still and low-velocity mixtures were made in a steel gallery approximately 6 by 6 by 4 feet. The gallery was equipped with a small mixing fan and a Sirocco blower to direct a stream of the mixture past the lamp. A predetermined amount of the gasoline was vaporized inside the closed gallery.

A Koehler permissible-type lamp was used in these tests. Thermocouples were attached to each gauze as a means of determining the gauze temperatures. A cathetometer mounted outside the gallery, opposite a gallery window, allowed close up observations of the flame and lamp interior.

The lamp was fitted with an internal ignitor by means of which it could be relighted without opening the gallery or removing the lamp.

Test Procedure

The lighted lamp was placed on a stool near the front center of the gallery, and the mixing fan was started; the desired amount of gasoline was then evaporated. The percentages used were 0.0, 1.1, 2.6, 3.3, and 3.9. With each percentage, gauze temperature readings were obtained corresponding to the following velocities of the mixture past the lamp: 0, 200, 400, 600, 800, and 1,000 feet per minute. Whenever the lamp was extinguished it was relighted, except in some cases in which no sustained burning could be obtained. In addition to the temperature readings, the behavior of the lamp was observed by means of a cathetometer.

Test Results

The following observations were made:

1. At each percentage of gas in which sustained burning was obtained in the lamp, the greatest temperatures were obtained in very low-velocity movement, below 100 feet per minute, of the mixture past the lamp. At higher velocities the effect of the increase in the quantity of gas burning in the lamp seemed to be more than offset by the increase in loss of heat to the air current, and the gauzes became cooler.

2. Under any condition of velocity the temperature of the gauzes increased with increase in percentage of gas. This, however, was true only up to the lower explosive limit of the mixture, because burning within the lamp invariably ceased when in explosive mixtures.

3. The maximum gauze temperatures obtained in still mixtures were 324° C. with the inner gauze, and 218° C. with the outer gauze. These temperatures increased to 350 and 300° C. in a velocity of 1,000 feet per minute.

No ignition of a mixture external to the lamp was obtained, and the temperature of the outer gauze was always less than 50 percent of the temperature necessary to produce an ignition of the vapor mixtures by a lamp gauze.

BEHAVIOR OF LAMP FLAMES IN VARIOUS PERCENTAGES OF VAPOR

Tests in various percentages of vapor consisted of placing or carrying lighted lamps into a test gallery, evaporating the desired amount of the gasoline, and observing the behavior of the flames. The following lamps and equipment were used:

1. Four permissible-type lamps -- Koehler flat wick, Koehler round wick, Wolf flat wick, and Wolf round wick.

2. A 4 1/2-cubic foot steel gallery equipped with paper relief head in case of an explosion.

3. A 1,000-cubic foot glass gallery for check tests in low-percentage mixtures.

4. A cathetometer for observing the flames in the 4 1/2-cubic foot gallery.

5. Thermal-conductivity apparatus for analyzing mixtures.

6. Vacuum sample bottles for combustion analyses.

7. Gas masks for tests in 1,000-cubic foot gallery.

<u>Tests in 4-Cubic Foot Gallery</u>

The gallery was placed in a dark room for observation of low flames. Two and sometimes three lamps lighted with low flames were placed in the gallery directly in front of the observation window. A desired amount of the gasoline was evaporated, and the changes in heights of the gas caps were noted. Samples of the mixture were taken at approximately the same time as the observations. The samples were analyzed directly by means of the thermal-conductivity apparatus or were taken for combustion analysis by means of vacuum bottles broken inside the gallery. Observations were made in various mixtures from 0 to 1 1/2 percent.

A similar series of tests was made using wick flames approximately seven-eighths inch in height and noting the changes in flame height at each percentage.

Check tests were made in low-percentage mixtures in a 1,000-cubic foot gallery. The gallery was made semidark. The flames were adjusted outside the gallery, and the lamps were then carried into the gallery by the observers, who

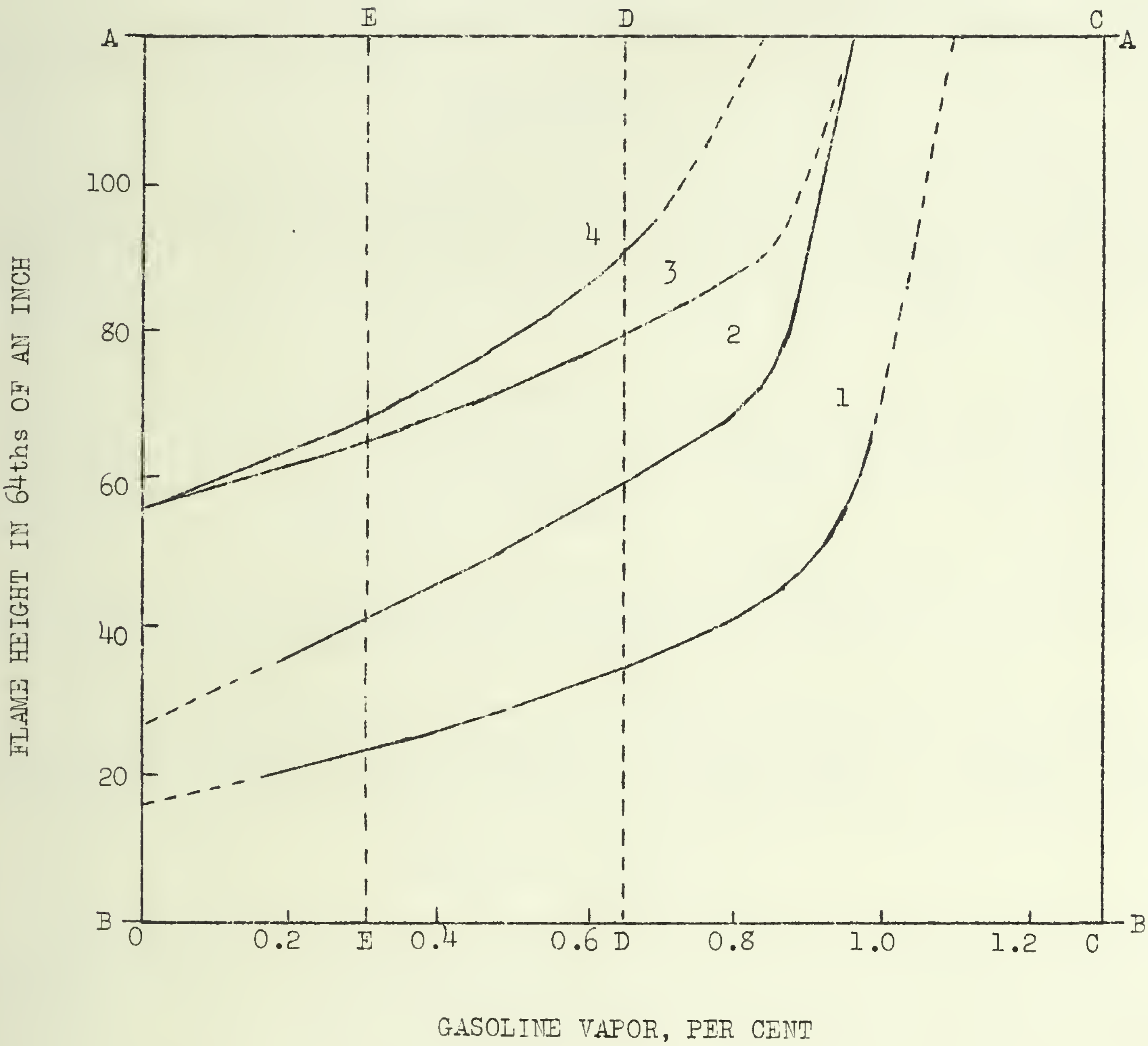

Figure 1. - Height of flames of round and flat wick lamps in casing-head gasoline vapor and air mixtures. Curve 1, round-wick lamp, low testing flame; curve 2 - flat-wick lamp, low testing flame; curve 3, round-wick lamp, high (7/8 inch) testing flame; curve 4, flat-wick lamp, high (7/8 inch) testing flame.

wore gas masks. After observing the change in flame height of each lamp, the flame was lowered until just a trace of yellow flame was visible, and the height of the gas cap was noted.

Tests were made in gas mixtures of zero to 0.8 percent, using two flat-wick and two round-wick lamps.

Test Results

Figure 1 shows the variations in heights of flames of both round-wick and flat-wick lamps, with percentage of gasoline vapor. Curves 1 and 2 show the average values obtained with the round-wick and flat-wick lamps with their flames adjusted in air until just a trace of yellow tip remained. Curves 3 and 4 are the corresponding values obtained with flames adjusted in air to seven-eighths inch.

The line A-A represents the top of the lamp glass; the zero line B-B represents the top of the wick tube and therefore the bottom of the flame; line C-C represents the lower explosive limit of the gasoline vapor used in this investigation. This value was obtained by determining the minimum concentration that could be ignited in the gallery.

The line D-D represents one-half the lower explosive limit percentage value. The line E-E is approximately the maximum concentration into which men may enter without being equipped with gas masks.

In the low percentages, low-flame readings were impossible; in the higher concentrations the high flame of both types of lamps and the low flame of the round-wick lamps became too unstable to permit definite readings. These parts of the curves are therefore shown in short broken lines.

DISCUSSION OF RESULTS

An investigation of the behavior of a flame safety lamp in vapor and air mixtures was made by Wilson and Wilken,[6] who used a flat-wick Koehler lamp. Their vapor, however, was hexane, whereas that used in the bureau's tests was mostly pentane. They used a smaller gallery, of approximately 0.7-cubic foot volume, as compared with the 4 1/2 and 1,000-cubic foot galleries used in the bureau's tests.

It is interesting to note that in both investigations the maximum rise in height of the long or lighting flame was about one-half inch.

6/ Wilson, R. E., and Wilken, R. E., Use of Koehler Safety Lamp in Testing Tanks for Combustible Gases or Vapors: Industrial and Engineering Chemistry, vol. 16, 1924, pp. 1154-1156.

The chief difference in the results obtained was in the relative elongation of flames of different heights. For example: Whereas between the vapor percentages 0.32 and 0.8, the difference in rise of the three-eighths inch and seven-eighths inch flames was about 40 percent in the bureau's tests, the rise of the seven-eighths inch flame being greater, Wilson and Wilken obtained a difference of more than 300 percent for these flames. Much of this difference may be due to reading the short flames under different conditions. The low flame in low-percentage mixtures does not have a well-defined top; consequently it is difficult to see and takes longer to observe.

Part of the present tests were made in a large gallery into which the observers could carry the lamps. Under this condition it is possible, by moving the lamp and causing relative motion between it and the flame, to detect the real top of the gas flame more readily.

The bureau's tests indicated that the superiority of one flame over another was not so much in the relative change in heights as in the visibility and stability of the flame. A high or full luminous flame is more easily seen than a low flame and is much less liable to be extinguished by bumping the lamp. A low flame can be adjusted in the mixture to be examined and no correction need be applied. A low flame is thus independent of changes in the flame height that may occur as the lamp is being carried into or out of a tank. The tests showed that in concentrations up to 0.3 percent, a lamp of either type used in this investigation is unsatisfactory as a detector because a low-flame gas cap does not have a well-defined top, and in general does not have enough body to be readily seen. A high flame has such a small (one-eighth inch) change in height at this low percentage that it is difficult to observe.

The rise of either the short or long flame in a percentage of half the lower explosive limit was about one-fourth inch for the round-wick lamps and three-eights inch for the flat-wick lamps.

ACKNOWLEDGMENT

The writers wish to acknowledge the helpfulness of L. C. Ilsley, electrical engineer, Pittsburgh Experiment Station, under whose supervision the investigation was made.

Circular 6084,
October, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

CONSUMPTION OF PRIMARY OR VIRGIN TIN IN THE UNITED STATES, 1927 [1]

By J. B. Umhau[2]

Early in 1928 a canvass to ascertain the amount of tin consumed by each of the various uses in the United States during 1927 was undertaken in response to an active demand by industry for further information on the subject. In the United States the consumption of tin requires annual imports amounting to about half of the world production of that metal. The results of this inquiry, wherein effort was made to eliminate figures relating to secondary tin, account for 68,797 long tons of primary tin, a quantity equivalent to 96.7 per cent of the imports in the same year. The results tabulated below are based on the reports of 1,050 concerns.

In the manufacture of tin plate and terneplate, the principal tin consumers, 24,527 long tons of primary tin were used, accounting for 35.65 per cent of the total consumption of primary tin in the United States in 1927. Next in order of magnitude as a consumer is solder, which required 13,734 long tons, or 19.96 per cent of the total. The manufacture of babbitt required 8,705 long tons, or 12.66 per cent of the total consumption, and foil and collapsible tubes consumed 6,903 long tons, or 10 per cent of the total.

A canvass made by the Bureau of Mines in 1926 of the tin consumed in the United States in 1925 accounted for consumption of 117,406 long tons of tin, including both primary and secondary tin. This amount is approximately 13,000 long tons in excess of the indicated supply that became available in that year. Concerning this excess, Information Circular 6019, "Consumption of Tin in the United States, 1925," says:

"Unquestionably, however, a part of this unaccounted for metal may be attributed to the short service rendered by the finished article and the rapidity with which it finds itself again in the melting pot; thus the metal may be reused several times during a year. . An inference that might be drawn from the study is that the accumulated free stocks of tin are never high."

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2 Common metals division, economics branch, Bureau of Mines.

Consumers' stocks available for use in 1925 and the consumers' drafts on these stocks could not be determined. Therefore it is impossible to gauge the extent to which the use of stocks entered into the apparent excess. Furthermore, a part of this excess is probably ascribable both to errors in the reports of the consuming concerns and to errors in interpretation of these reports. Such errors are inherent in first studies of this kind and only repeated canvasses can eventually eliminate them.

Because of the reasons given and because in compiling the following table every effort was made to include only figures relating to primary or virgin tin, the figures herein presented for consumption in 1927 are not comparable either with those presented in Bureau of Mines Circular 6019, or those relating to 1917 compiled by the War Industries Board.

The Bureau of Mines will continue its effort to determine the annual consumption of tin. It is planned to include in the canvass relating to 1928 the consumption of secondary tin and consumers' stocks, in order that satisfactory data on the total tin consumption of the United States may be established.

Primary or Virgin Tin Consumed by Various Uses in the United States During 1927

Uses	Long tons	Per cent
Tin plate and Terneplate	24,527.5	35.65
Solder	13,734.7	19.96
Babbitt	8,705.9	12.66
Foil	4,193.4	6.10
Bronzes and brasses	2,988.9	4.34
Castings	2,974.1	4.32
Collapsible tubes	2,709.6	3.94
Tinning brass, copper tubes, sheets or shells, nails, etc.	2,657.1	3.86
Chemicals	2,620.5	3.81
White metal	850.0	1.24
Tin oxide	721.1	1.05
Type metal	449.9	0.65
Other alloys	176.3	0.26
Miscellaneous	1,488.0	2.16
Total	68,797.2	100.00

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4878

Circular No. 6085
October, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

MINE EXPLOSIONS IN THE UNITED STATES DURING THE FISCAL YEAR ENDING JUNE 30, 1928 [1]

By D. Harrington [2]

The attached tabulation gives data concerning explosions in the United States to which the attention of the United States Bureau of Mines was directed during the year June 30, 1927, to July 1, 1928. One of the explosions which killed two men was at a metal mine, and was caused by methane ignition from an open light; the other 30 explosions occurred in coal mines, and resulted in a total of 340 fatalities. Explosions listed in the table are not restricted to major disasters (those causing five or more fatalities), as in some of the instances listed there were no fatalities and in others only one, two, three, or four.

Twenty-four of the ignitions were in bituminous mines, 6 in anthracite, and 1 in a metal mine; there were 321 fatalities in the 24 explosions in bituminous mines, 19 fatalities in the 6 anthracite explosions, and 2 deaths in the 1 explosion at the metal mine.

Ignition was caused by electricity in 14 explosions from which 282 fatalities resulted; open lights or smoking were responsible for 12 ignitions and 49 deaths; explosives caused 3 ignitions and 9 deaths; and in 2 explosions causing 2 deaths the igniting cause was not ascertained.

Of the 31 explosions (including the explosion in a metal mine) 14 were in open-light mines, causing 51 fatalities; 15 were in closed-light mines, causing 289 fatalities; and the data are not available as to lighting method in 2 mines where 2 explosions took 2 lives. In the 14 explosions in open-light mines, 9 explosions with 41 fatalities were started by open lights which ignited methane, 3 with 9 fatalities were due to ignitions from blasting, and 2 with 1 fatality were of unknown origin. Of the 15 explosions in closed-light (electric cap lamp) mines, 14 with fatality toll of 282 were of electrical origin and 1 with 7 fatalities was charged against smoking, though there was a strong suspicion that the cause may have been electrical also.

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2 - Chief engineer, safety division, U. S. Bureau of Mines.

The fact that 15 out of the year's 30 explosions in coal mines (omitting the one from the metal mine) were in closed-light mines and that 14 of the 15 (possibly the entire 15) were of electrical origin is decidedly disquieting, indicating one or both of the following conditions: Relaxation of precautionary measures as to ventilation when closed lights are installed; or, the presence of an electrical hazard, existing either in the electrical installations or electrical practices or in both in our mines, which manifests itself much more definitely in closed than in open light mines.

The electrical ignitions (all of methane) were as follows:

Nonpermissible electrical mining machine	2
Nonpermissible storage-battery locomotive	3
Mining machine nips or nipping	3
Trolley locomotive	2
Cable of combination trolley-cable reel locomotive	1
Cable-reel locomotive	1
Multiple shot-firing battery	1
Faulty wiring	1
	14

In addition there were two ignitions where mining machines were suspected, though the cause was actually ascribed to smoking in one case and to an open light in another. In several instances smoking in closed-light mines was suspected as the igniting cause, though later on the responsibility (except in one instance) was placed elsewhere. The flame safety lamp was under suspicion in a few cases, but later was "absolved of blame."

With the exception of the three explosions caused by explosives, all of the ignitions concerned methane primarily, though in many instances coal-dust undoubtedly later entered into the extension of the affair.

Of the 24 bituminous mines in which explosions are known to have occurred during the fiscal year ending June 30, 1928, 10 are reported as having used rock-dust, 11 had never used rock-dust, and data as to rock-dusting in 3 are not at hand. There were 258 fatalities in the 10 mines reported as having used rock-dust, and 62 fatalities occurred in the 11 mines which are reported as not having at any time used rock-dust. Generalized rock-dusting had been in effect in none of the 10 mines reputed as having used rock-dust, and in most of the mines probably not as much as 1 per cent of the mine had at any time been rock-dusted. Although rock-dust is said to have been of aid in some instances in reducing the area covered by the explosion and although credit has been given rock-dusting in a few cases as having contributed to saving of life, it is improbable that the comparatively small amount of rock-dusting which has been done in any of these mines contributed much toward preventing extension of the explosion. At any rate, the most disastrous explosion of the year (as was also true of the preceding year) was in a so-called rock-dusted mine; in both instances, however, no claim was made that the mine in question had ever been thoroughly rock-dusted over all surfaces in all accessible parts of the mine, or that the rock-dusting had been kept up-to-date.

The outstanding lessons of the explosion record of the past year are that ventilation is undoubtedly being neglected in many of our coal mines, especially in many of our closed-light mines; that there is carelessness in installation or operation (or both) of electrical equipment in mines which give off explosive gas, especially in those which are using closed lights; that rock-dusting is not being done in nearly as many coal mines as it should be; and that in the comparatively few mines which are using it the rock-dusting is not being even approximately done or maintained in anything like an adequate manner. The bright side of the picture is that explosions and explosion fatalities from open-light ignitions are being reduced materially, undoubtedly because of the rapid extension of the use of closed lights; it is now estimated that more than half of our coal tonnage comes from closed-light mines. The number of explosion disasters with loss of life from use, or rather misuse, of explosives seems to be reaching almost the vanishing point, partly because of the use of permissible explosives and partly because much of the blasting is now done when the working shift is not in the mine, so that any explosions which do occur from blasting usually result either in no loss of life or else in a life loss which is confined to a very limited number.

SUMMARY OF MINE EXPLOSIONS BY STATES, JULY 1, 1927, TO JUNE 30, 1928, INCLUSIVE

States	Lights				Fatalities and ignition causes									
	Open	Closed	Unknown	Total	Electricity		Open light or smoking		Explosives		Unknown		Total	
					Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions
Alabama	3			3			2	3					2	3
Arkansas	1			1			13	1					13	1
Illinois		2		2	21	1	7	1					28	2
Kansas	1			1					0	1			0	1
Michigan[1]	1			1			2	1					2	1
Oklahoma	1	1	1	3	3	1			1	1	0	1	4	3
Kentucky	1	2		3	15	2			8	1			23	3
Pennsylvania	1	7	1	9	224	7	4	1			2	1	230	9
Washington		2		2	2	2							2	2
West Virginia	5	1		6	17	1	21	5					38	6
Totals	14	15	2	31	282	14	49	12	9	3	2	2	342	31

1 Metal mine.

The above table is a record of explosions in the United States to which the attention of the safety division of the United States Bureau of Mines was directed during the fiscal year July 1, 1927, to June 30, 1928.

Circular No. 6087
November, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE--BUREAU OF MINES

ROCK-DUSTING BY HAND METHOD[1]

By D. Harrington[2] and C. W. Owings[3]

The belief is now fairly general among the coal-mining people of the United States that one of the most effective methods of preventing wide-spread coal-mine explosions is that of introducing rock-dust into coal mines to reduce the inflammability or explosibility of dusts found on mine surfaces. Notwithstanding this belief it is improbable that even a small fraction of 1 per cent of the coal mines of the United States are at all adequately protected by rock-dust; in a survey made in the summer and fall of 1927 it was found that but 463 out of more than 7,000 operating bituminous and lignitic coal mines were using rock-dust at all, and that few if any of the 463 were fully or adequately protected by rock-dusting.

Inspections of a large number of mines through the United States by Bureau of Mines safety division field men have failed to reveal a single adequately rock-dusted mine, yet there is no doubt that many of the owners and operators believed their properties to be fully protected by rock-dust against the much-feared hazard of widespread explosion. Two of the most disastrous explosions of recent years occurred at properties where the owners were definitely of the belief that the rock-dusting done had made the mines immune to widespread explosion involving coal-dust. In both instances it was found that although some rock-dusting had been done, the mines were more nearly 1 per cent than 100 per cent rock-dusted.

This condition as to inefficiency or insufficiency of rock-dusting in the coal mines of the United States is almost universal, and unless our mining men awaken to its dangers, the disaster record of the coal-mining industry is much more likely to become worse than better. During the fiscal year ended June 30, 1928, the attention of the safety division of the United States Bureau of Mines was called to 22 explosions with 320 fatalities in bituminous coal mines of the United States; and of the 22 explosions there were 10 with 258 fatalities in mines that were listed as having used rock-dust; upon investigation it was found that as usual the rock-dusting had been anything but comprehensive or adequate.

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2 Chief engineer, safety division, U. S. Bureau of Mines.

3 Associate engineer, safety division, U. S. Bureau of Mines.

It is probable that in a very few instances last year the relatively small amount of rock-dusting stopped the extension of the explosion and thus prevented further expansion of the death list. In general, however, the explosions occurred in a part of the mine that had not been rock-dusted - and right here is the crux of the failure or probable failure of present-day rock-dusting in the United States. There should be no part of any bituminous or lignitic coal mine in which all of the exposed surfaces (roof, ribs, and floor) have not been thoroughly rock-dusted and kept thoroughly rock-dusted. In other words, all exposed surfaces of all accessible places in bituminous and lignitic coal mines should be kept covered with rock-dust so that the combined rock-dust-coal-dust mixture at all times and in all places has less than 35 or 40 per cent combustible matter. The only exception to this rule is that surfaces which are wet (and this does not mean merely damp) need not be rock-dusted. However, a mine opening may have several inches of water on the floor and yet have much explosive dust on the ribs and roof above the water; in such places the ribs and roof should be kept rock-dusted, irrespective of the wetness of the floor.

There are many reasons why rock-dusting has not been more widely adopted and why it has not been done more efficiently where it has been adopted in principle. The greatest trouble is that mining men seem in general unable to grasp the underlying principles of rock-dusting; many of the attempts at rock-dusting of mines would be amusing or ridiculous if they were not tragic or at least likely to become tragic. Rock-dusting is intended chiefly to prevent <u>coal-dust</u> from extending explosions which have been started; and since explosions may start at practically any point in a mine, it is, or at least should be, obvious that every point in the mine which has explosive dust should have protection against the feeding of the explosion by the dust. Since as little as 1 pound of bituminous or lignitic coal-dust per linear foot of ordinary entry will feed or extend an explosion, it is easy to see that practically all mine openings have a sufficient quantity of dust present to be dangerous. There is absolutely no question that all bituminous and lignitic coal mines, whether gassy or so-called nongassy, require thorough rock-dusting of all accessible surfaces that are not decidedly wet, unless the settled dust has less than 35 or 40 per cent combustible matter.

Up to the present, rock-dusting has not been recognized as a necessary daily operating practice, and until it becomes as fully a matter of routine daily procedure as timbering, blasting, ventilating, loading, and hauling, rock-dusting is certain to fail as a sure preventive of widespread disasters. At present the best of our rock-dusted mines keep possibly 25 per cent of the mine surfaces adequately covered with rock-dust and some of our so-called rock-dusted mines have only a fraction of 1 per cent of the surfaces covered. Frequently a main haulage road is well rock-dusted while its 1, 2, 3, and up to 6 or 7 parallel air courses (the surfaces of which are dry and covered with explosive dust) are absolutely devoid of protection, the situation resembling much the completeness of the hiding of the ostrich when he sticks his head in the sand.

In some instances three or more main entries, including the main haulage road and its parallel air courses, are fairly well rock-dusted, but no attention is paid to the side entries from which the rooms are turned and in the vicinity of which are the most of the operations likely to bring about an explosion. And there are so few mines which rock-dust the rooms or the open abandoned places in mines that their total number in the United States can undoubtedly be designated by the fingers of one man's hands.

One of the many factors which have prevented widespread and adequate rock-dusting is the almost unanimously accepted inference in the United States that rock-dusting can be done only by machinery; up to the present no machine has been available that would keep all types of accessible mine surfaces adequately covered with rock-dust or that would do it without a considerable expenditure of labor and money. It is true that there are excellent machines for the comparatively inexpensive and effective rock-dusting of mine openings where trolley lines are available for the operation and transportation of the machine, but generally these machines are comparatively ineffective or at least very costly for the rock-dusting of regions where there is no track or no trolley wire; there are mechanical means of rock-dusting trackless places by high-pressure blowers or compressed air, but these methods are somewhat expensive and cumbersome.

In so far as room treatment is concerned, probably the worst handicap to the widespread rock-dusting of mines is the fact that air currents are almost invariably sluggish in rooms and the use of any kind of mechanical rock-duster throws such large quantities of dust into the air that room air currents fail to take the dust away quickly or effectively enough to allow the workers operating the rock-dusting machine to remain in any one place a sufficient time to do the dusting thoroughly. The machine operators are at so much disadvantage in seeing and breathing while room-dusting that rarely is the rock-dusting well done. Moreover, it is far more difficult in room than in entries to reach the longer distances to the ribs or through the timbers or gob; and in low coal although the entry roof is usually brushed to give head room, the room roof is seldom brushed, so that rock-dusting of such rooms by machine becomes almost impossible. For these as well as other reasons rooms are seldom rock-dusted.

Up to the present, rock-dusting of coal mines in the United States has been considered as almost wholly devolving upon the operating company, and in general the underground workers are relieved of any part or responsibility or even interest in the matter; in fact, it is curious to note the apathy of the miners toward rock-dusting. Rarely does one find a rock-dust advocate among the rank and file of the mine workers, and even more rarely is any concerted demand made by them for the introduction and maintenance of adequate rock-dusting of mines. There is absolutely no question that rock-dusting is of fully as much benefit to each and every one of the underground workers as it is to the operating company, and there is no good reason why the mine worker should not shoulder some of the burden and responsibility of making the mine safe for himself and his coworkers. It is very probable that not until the miner shoulders

his share of the responsibility for the maintenance of rock-dusting in mines will our coal mines be kept adequately rock-dusted.

In many of our coal mines, especially in the western part of the United States, water under pressure is piped by the company to or near the working face and the face worker is supplied with water hose and is required by custom, by company rule, or by law (or by all three) to keep the face region watered or sprinkled; in at least some mines the miners do the watering thoroughly, because it is they who benefit chiefly by the lessened amount of dangerous and unhealthful dust which gets into the air when the coal pile, top of loaded coal cars, and face surfaces are not kept well watered. Here the company and the workers share the responsibility, the company in placing the water under pressure and providing the water hose, the workers in using the hose and water to help make their places and the entire mine more safe and more healthful. There is absolutely no valid reason why essentially the same system can not be used with rock-dusting and there is every reasonable argument why it should be in effect. Every mining company operating a bituminous or lignitic mine in the United States and having any underground workings which are not absolutely wet, should be required to keep on hand at a reasonable distance from every working face or place that is not absolutely wet a plentiful supply of rock-dust suitable for rock-dusting to prevent explosions, and the rock-dust should be supplied as freely and as systematically and consistently as timber, or rails, or ties, or empty cars. The face worker should be required to throw this dust by hand or by shovel or some similar method against the ribs, roof, timbers, and floor so as to have on entry room and cross-cut surfaces 5 to 10 pounds of rock-dust per linear foot of advancing opening. These requirements should be part of the State law and every State coal mine inspector of bituminous or lignitic mines should be expected to enforce these requirements in all mines large or small, with at least as much vigor and diligence as he enforces laws or regulations as to timbering and ventilation.

Under the ordinary methods of mining, very few entries or rooms advance more than 5 feet per day; hence to cover the surfaces with the required 5 to 10 pounds of rock-dust per linear foot of advance would require 25 to 50 pounds of rock-dust per shift, the placing of which should not require more than 10 or 15 minutes of the miner's time. Surely this is no "burden" which the face worker should dread, and just as surely it is one which he can not afford to shirk or avoid.

A mine operating in a 5-foot seam with entries and crosscuts 12 feet wide, rooms 22 to 24 feet wide, and an output of about 1,000 tons per day from advancing rooms and entries will ordinarily produce approximately 25 per cent of the coal from narrow (entry or crosscut) work and 75 per cent from room work, hence there will be a daily advance of about 100 feet in narrow work and of 150 to 175 feet in room work. If the face workers place 5 pounds of rock-dust per foot of narrow work and 10 pounds per foot of room advance, the total rock-dust consumed per day by the face workers in hand-dusting would be about 500 pounds in the narrow work and 1,750 pounds in the room work, a total of 2,250 pounds or 1 1/8

tons of rock-dust per shift. Thus in a mine producing 1,000 tons a day about 1 ton of rock-dust per day will keep all of the advancing faces in a 5 or 6 foot seam thoroughly rock-dusted, and the mine will undoubtedly be much more adequately dusted than has been true of any mine in the United States to date. Rock-dust f.o.b. the mine usually costs less than $10 per ton and at least in some localities can be had for as little as $5 per ton; hence the system of rock-dusting by which the company supplies the dust and the face worker applies it to the mine surfaces as the workings advance, will give thorough rock-dusting to so-called trackless as well as to track or haulage mine openings at an expense to the mine of much less than 1 cent per ton of coal produced, and the 10, 20, or 30 minutes per day, or possibly every alternate day, used by the miner in the distribution of the rock-dust is most certainly not an unreasonable contribution on his part to the safety of the mine and its workers, including himself.

Rock-dusting by hand does not generally place in the air any considerable amount of dust, hence the hand-dusting of rooms or other regions with sluggish ventilation is done with practically no difficulty. The rock-dust should not be mixed with the coal as it is shot down, therefore the hand rock-dusting of the advancing regions should be done after the coal has been loaded out; preferably it should be done as one of the last acts of the face worker before he leaves his place to go home. The rock-dust should not be thrown against the face to be shot down or on the immediate floor on which the coal will fall after blasting. The ideal condition is obtained when the actual face and surfaces for a distance 25 to 40 feet back from the face are kept wet by water from a hose and the rock-dusting by hand is maintained on advancing surfaces up to about 25 to 40 feet of the actual face.

When the hand rock-dusting of the face by the worker using rock-dust supplied by the company is arranged for, the matter of maintaining in a safe condition the rock-dusting of the haulage entries and other places as the faces advance will remain. This will be the duty of the company. With the good basic coating done by the face worker the burden of maintenance should be light, and in fact should be confined almost wholly to haulage entries and to the non-haulage workings where travel is done. Where rock-dusting machines can be used there should be little trouble in redusting 1,000 to 2,000 or more feet of haulage road in an 8-hour shift, and with the before-mentioned heavy basic coating placed on the air course or other trackless entry surfaces by the hand dusting when on advance, redusting can generally be done effectively and advantageously in these trackless places by using the air currents.

A sufficient number of samples of dust should be gathered each month on each split of air and tested either by chemical analysis or other method acceptable to the inspector to determine if any part of the mine requires redusting. A sample should be taken in the following manner: A groove 6 inches wide across a floor from rib to rib should be made in the loose, fine material, by scoop or other means, to a depth of 1 inch, if feasible. Also a 6-inch strip of dust should be brushed from both ribs, roof to floor, and from rib to rib along the roof if dust is adhering to the roof; where the entry has timber sets,

a dust sample should be brushed from the top of one collar to 6-inch width, if feasible, and from the lagging, if any. All the material thus sampled should be screened through a 20-mesh sieve before being tested. The sample from the floor should be taken and analyzed separately from the rib, roof, and timber sample; this is important. Such mines or parts of mines where the fine material (dust) is considered to be sufficiently wet not to require rock-dusting should be sampled at least once a month; the samples should be analyzed to show the moisture content and a copy of the analytical results sent to the mine inspector. Whenever such samples show a moisture content of less than 25 per cent, the fine material (dust) in the mines or parts of mines should be considered of an explosive nature, and rock-dusting should be done. A record should be kept in a book provided for that purpose, showing the location at which samples have been taken and the results of the analyses or tests.

Moreover, when necessary to redust trackless places the dusting can be done by hand methods much less expensively than is usually believed, unless access to these areas is particularly difficult. In a Pennsylvania mine over 1 mile of entry was hand-dusted at a cost of a little over 7 cents per linear foot of entry and with placement of about 7 pounds of dust per foot; the cost of machine-dusting in this mine, including labor and material, was 4 cents per linear foot of entry with placement of 6 pounds of rock-dust per linear foot of entry. In another Pennsylvania mine, hand-dusting costs 4 cents per linear foot of entry, using but 3 pounds of dust per foot, and machine-dusting costs but $2\frac{1}{2}$ cents per foot, using the same amount of dust. In another mine in Pennsylvania a relatively small amount of hand-dusting of entries cost $4\frac{1}{2}$ cents per linear foot, using $4\frac{1}{2}$ pounds of dust per foot of entry; and a comparatively inefficient machine covered a much larger footage of entry with $5\frac{1}{4}$ pounds per linear foot at a cost of $5\frac{1}{4}$ cents per foot. In an Illinois mine two-men crews hand-dusted much entry footage, carrying dust in pails and throwing it by hand, the cost being 5 cents per foot and the quantity placed about 8 pounds per foot of entry. The track entries in one Pennsylvania mine were dusted with $3\frac{1}{4}$ pounds of dust per linear foot at a cost of $2\frac{1}{2}$ cents per foot, and trackless entries were hand-dusted with $9\frac{1}{4}$ pounds of dust per linear foot, the cost being $6\frac{1}{4}$ cents per foot; here the cost of hand-dusting the trackless entries was more than double that of machine-dusting the track entries, but the larger quantity of dust placed in hand-dusting the trackless entries was much the more efficient and in the long run the least costly.

In connection with the rather expensive hand-dusting of trackless entries in the last mine cited, an estimate was made of the relative costs of hand-dusting the trackless entries and of erecting up-to-date rock-dust barriers, the protection of the region by actual hand-dusting being slightly over $800 against an estimated cost of about $3,200 for the barriers; the hand-dusting is much the more reliable, and probably the more durable, in addition to costing only about one-fourth as much as the barriers. Although rock-dust barriers when properly constructed and maintained have definite value in the retardation or limiting of explosions, yet at least 90 per cent of the rock-dust barriers as installed in mines are practically valueless; hence time and money invested in efficient hand rock-dusting will be far more likely to repay with the necessary protection of

the mine and its workers than the fruitless expenditures of time, money, and effort now going into rock-dust barriers almost wherever they are placed in operating mines.

About a year ago a mine-safety man, who enters many mines in various parts of the United States, was asked to designate the best rock-dusted mine he had seen. Later it was found that the mine chosen had been rock-dusted wholly by hand at a cost of about 5 cents per linear foot of entry, no rooms being rock-dusted. In a summary of Paper No. 2 as to rock-dusting by the Safety in Mines Research Board of Great Britain, a British authority says: "The stone dust can be scattered by hand or it can be distributed by the ventilation current or by mechanical sprayers. Each of these methods is used, but scattering by hand appears to be often the best way to remove the fine coal-dust (which is most dangerous) from the upper surface of timbers to replace it with stone dust." From this statement it is apparently customary to do much hand rock-dusting in Great Britain.

In conclusion it appears that there is every reason why the face worker should rock-dust by hand as the face progresses, and that the rock-dust should be supplied to him by the company as rails, ties, and timbers now are. This will insure that all surfaces of advancing openings have at least one coating of rock-dust and will also render the protection of those surfaces much less difficult later on when the face region has gone forward. This method also distributes the responsibility, for since both mine workers and company are protected by rock-dusting it is fair and equitable that both should aid in securing the protection. The ideal method of protection against widespread explosions is to have the mine sufficiently ventilated to hold the methane content of mine air below 1 per cent at all times and in all places; to use permissible explosives with electrical detonation, and preferably to have all loading and firing done after the general working shift is out of the mine; where electricity is used to employ nothing but permissible electrical equipment and to hold open wiring, motors, and switches away from gassy or dusty faces as much as possible; to have the mine piped with water lines to all working faces and to use water on the cutter bar of all mining-machine cutting chains while operating and on all coal piles and roof, rib, and floor surfaces from the face back 25 to 40 feet while loading coal either by hand or by machine; to rock-dust by hand the region immediately back of the face as the face advances, leaving about 25 to 40 feet at the immediate face to be kept wet by hosing; and to have the company maintain the rock-dusting by machine, air-carrying, or hand-dusting of haulage and all other accessible places which periodical (preferably monthly) sampling indicates have incombustible less than 65 per cent, or in other words to redust when dust samples from mine surfaces show combustible above 35 per cent. The cost of this program is by no means as great as our mining companies usually apprehend, and at any rate the cost of the program is infinitely less than is the cost of widespread explosions such as have been occurring with monotonous regularity year by year in the United States.

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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE--BUREAU OF MINES

THE THIRD ANNUAL WEST VIRGINIA STATE SAFETY DAY MEET, BLUEFIELD, W. VA., SEPTEMBER 22, 1928 [1]

By J. J. Forbes[2] and Jesse Redyard[3]

The Third Annual West Virginia State Safety Day Meet was held on the Bluefield College Athletic Field, Bluefield, W. Va., on September 22, 1928, and without a doubt was the largest and most successful event of its kind ever held in the United States. Most of the coal mining companies and mining communities throughout the State of West Virginia were represented at the meet.

The number of people that attended the field day activities can safely be estimated at between 15,000 and 20,000. It was said that there were more than 3,000 automobiles parked on the Bluefield College athletic grounds at one time during the afternoon. Ideal weather conditions prevailed throughout the day. Although the week previous to the meet had been so rainy that arrangements were made in case of rain to hold the meet indoors.

The Annual West Virginia State Safety Day was first instituted and sponsored by Mr. Robert M. Lambie, Chief of the West Virginia Department of Mines in 1926. Through his untiring efforts and the cooperation of the U. S. Bureau of Mines, the coal mining companies of West Virginia, and their employees the event has become one of great magnitude. In 1926 the meet was held at Huntington on August 21 with 121 first-aid teams participating. The 1927 meet was held at Morgantown in the Mountaineer Stadium with 141 teams participating, and in 1928 180 first-aid teams, composed of white miner teams, colored miner teams, and boy scout teams, or approximately 1,080 men, participated in the meet at Bluefield. Practically every mining region in the State of West Virginia was represented by mine officials, miners, and their families. The States of Virginia, Kentucky, Tennessee, and Pennsylvania were well represented by mine operators and others.

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2 Supervising engineer, safety division, U. S. Bureau of Mines.

3 Foreman miner, U. S. Bureau of Mines Car No. 7.

Field Arrangement

The entire field was marked off with enclosures of ample dimensions to accommodate a first-aid team while working on a problem. There were 180 such spaces to accommodate all of the teams that participated. It was not possible to have all teams perform at one time, because there were not enough judges. This necessitated dividing the total number of teams into two groups or sections. In the first section there were 80 white miner teams and in the second section there were 100 teams divided as follows: 65 white miner teams, 27 colored miner teams, and 8 boy scout teams.

Three representative first-aid problems that involved the fundamental principles of first-aid work such as controlling bleeding, artificial respiration, physical shock, dressings for open wounds to prevent infection, simple and compound fractures and dislocations were worked by each team that participated in the meet.

One group of teams performed at one time while the other group was idle. A lay judge was assigned to each team as it performed and a supervising judge was assigned to a block of four teams. With a few exceptions the judges were men from outside the State of West Virginia and were safety engineers, State mine inspectors, mine operators, and miners who were sent to the meet by their respective companies or State mine departments. In addition there were 15 men from the safety division of the United States Bureau of Mines who participated in this meet as judges. All of the judges were well versed in first-aid work. Particularly was this true of the supervising judges, who were selected with the utmost care. The progressive system of judging was used in the contest, each judge alternating from Section 1 to Section 2, then to Section 3, and so on, progressing to the number of first-aid teams assigned him.

Three problems were worked by all participating teams. When the scores were finally announced, 11 teams were tied for first place. It was necessary for the teams to perform two tie problems to determine the winners of the meet.

Winners of the Meet and Prizes

There were three sets of prizes for the teams that participated in the meet, one set of prizes for the white miners, a second set for the colored miners, and a third set for the boy scouts. The scores of each of these groups were recorded separately.

An important feature of the State Safety Day was the awarding of the "Sentinels of Safety" trophy, which was presented by the Explosives Engineer to the Gary No. 2 mine of the U. S. Coal & Coke Co. at Gary, W. Va. This is the third consecutive year that the U. S. Coal & Coke Co. has captured the honors in the National Safety Competition as having the lowest accident record for the bituminous mines entered in the contest. The contest is conducted under the auspices of the United States Bureau of Mines.

Demonstration of Explosibility of Coal-Dust, and Use of Rock-Dust as a Preventive

One of the outstanding features of the day from the viewpoint of accident prevention was the demonstration of a coal-dust explosion in a specially constructed gallery situated at one end of the field and in clear view of all that attended the meet. There were two distinct demonstrations given on the field during the meet. The first demonstration portrayed what happens in a coal mine that is not rock-dusted, in the event of a blown-out shot or ignition of fire damp (methane and air). The second demonstration showed the effects of rock-dusting or, in other words, how coal-dust explosions may be prevented through the proper use of rock-dust. These demonstrations were made under the supervision of the United States Bureau of Mines. Both demonstrations were very effective in showing the explosibility of coal-dust and the use of rock-dust as a preventive of coal-dust explosions.

Speakers

A number of prominent speakers addressed the large gathering on safety and accident prevention work and kindred subjects.

Preparatory Training Work

All of the first-aid teams that participated in the contest at Bluefield were trained jointly by safety directors of the State Department of Mines of West Virginia and the United States Bureau of Mines first-aid instructors. The Bureau of Mines had seven instructors engaged in team-training in West Virginia for four weeks prior to the contest, and in addition the Bureau of Mines Safety Car No. 7 with two instructors assisted with the organization and training of the teams. Bureau of Mines Car No. 7 devotes its full time to training miners and officials in West Virginia in first-aid, mine-rescue, and other safety work. Its official headquarters is at Huntington, W. Va. To assist the State Department in training the large number of teams that participated in the contest it was necessary for the United States Bureau of Mines to take men from other mining districts in the United States. The States from which these men came are Montana, Indiana, Pennsylvania, Utah, and Alabama.

First-aid training is a part of the bureau's regular safety educational campaign in the mining, metallurgical, petroleum, and quarrying industries. Since the bureau came into existence in 1910 approximately 300,000 miners have been trained in first-aid and safety methods. The bureau cooperates to the fullest extent with State Mining Departments, mine operators, and others who are engaged in the promotion of safety and accident-prevention work; each year aid is given in one form or another to mineral industries in the promotion and handling of first-aid meets. For the fiscal year 1928 assistance and cooperation was given in the handling of 50 first-aid contests held in various parts of the United States, and in most instances the preparatory training work was done by Bureau of Mines employees.

The bureau maintains 10 safety cars and 11 safety stations situated in or adjacent to mining districts. The personnel of these cars and safety stations are actively engaged throughout the year in giving training to the employees and officials of the mineral industries in safety and first-aid methods.

The following tabulation of training conducted in the state of West Virginia from July 1, 1910 to June 30, 1928 shows that 23,180 men were trained in initial first-aid, 877 in mine-rescue work, 2,121 in combination training (first-aid and mine-rescue), 954 in additional first-aid training, 130 in additional mine-rescue training, and 27 in additional combination training (first-aid and mine-rescue). In other words, from July 1, 1910, to June 30, 1928, a total of 27,289 persons in West Virginia were given the Bureau of Mines complete course of training in first-aid and mine-rescue methods. In addition to the first-aid and mine-rescue training given by the bureau in the State of West Virginia during the fiscal year ending June 30, 1928, over 200 mine officials were given instruction in the advanced training course for mine-rescue and recovery operations following mine fires and explosions.

Number of Men Trained in West Virginia by the United States
Bureau of Mines During the Period
July 1, 1910, to June 30,1928

Period	Initial training			Additional training		
	F.A.	M.R.	Comb.	F.A.	M.R.	Comb.
July 1, 1910 to June 30, 1920	1,212	146	1,355	0	0	0
July 1, 1920 to June 30, 1923	2,962	274	425	285	14	15
July 1, 1923 to June 30, 1924	1,405	29	182	124	0	6
July 1, 1924 to June 30, 1925	3,859	115	124	365	9	4
July 1, 1925 to June 30, 1926	5,468	7	2	74	0	0
July 1, 1926 to June 30, 1927	4,548	0	6	32	0	0
July 1, 1927 to June 30, 1928	3,726	306	27	74	107	2
Total	23,180	877	2,121	954	130	27

Grand total number men trained --- 27,289

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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

HOW THE UNITED STATES BUREAU OF MINES CONDUCTS ITS NATIONAL OR INTERNATIONAL FIRST-AID CONTESTS[1]

By J. J. Forbes[2]

INTRODUCTION

The United States Bureau of Mines in carrying on its safety educational work in mining and allied industries maintains 10 railroad safety cars and 11 safety stations at strategic points in mining districts of the country. The personnel of these cars and stations, in addition to other duties, gives instructions in first-aid to employer and employees in their respective districts. Since the Bureau's training program was inaugurated in 1910 to stimulate accident prevention in the mining industry, nearly 300,000 persons have been trained in first-aid, mine-rescue, and safety work. Much of the work is carried on in cooperation with mining organizations and State mining departments. As a stimulus in promoting accident prevention a large number of competitive first-aid contests are conducted in the various mining districts each year; during the fiscal year 1928 more than 50 such contests were conducted by various companies, organizations, and State departments with the assistance and cooperation of the Bureau of Mines. In many localities the meets are held as elimination contests to determine the most proficient first-aid team in the district, which will be designated to represent that district in the national or international contest.

PRELIMINARY ARRANGEMENTS FOR CONTESTS

A national or international contest is generally held each year; it is conducted by the Bureau of Mines in cooperation with a group of mining companies and the local chamber of commerce or mining organization which sponsors and assumes the financing of the contest.

The following tabulation shows the number of teams participating and the States represented, together with location and dates of past national or international contests.

1 The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"
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NATIONAL OR INTERNATIONAL FIRST-AID CONTESTS, 1911 to 1928

Place held	Date	First-Aid Teams	Mine-Rescue Teams	States Represented
Pittsburgh, Pa.[1]	October, 1911	41	4	10
Terre Haute, Ind.	September, 1914	29	8	3
San Francisco, Cal.	September, 1915	26	7	12
Pittsburgh, Pa.	September, 1919	83	24	16
Denver, Colo.	September, 1920	73	20	20
St. Louis, Mo.	September, 1921	63	16	17 and Canada
Salt Lake City, Utah	August, 1923	55	21	13 and Mexico
Springfield, Ill.	September, 1925	55	10	15
San Francisco, Cal.	September, 1926	44	14	13
Pittsburgh, Pa.	August, 1927	47	17	12
Butte, Montana	August, 1928	46	12	11

1 The Pittsburgh meet in 1911 was merely a demonstration to arouse interest in the work.

In conjunction with the national or international first-aid contests a mine-rescue contest is also conducted, and the number of teams participating in past years is shown in the tabulation.

The city in which the contest is held is selected by the officials of the safety division, with the approval of the Director of the Bureau of Mines and Secretary of Commerce, only after careful consideration of the location with relation to the mineral industries, transportation facilities, hotel accommodations, and similar features. In addition, the city selected must guarantee the necessary money for financing the contest. The Director of the Bureau of Mines officially notifies the agency sponsoring the contest that its request has been favorably acted upon, after which a local organization is effected and a committee appointed who cooperate with officials of the Bureau of Mines. This committee takes care of the local publicity campaign while the Bureau of Mines, through the technical press and by special invitations to heads of mining companies, covers the broader or national publicity.

A suitable site for the contest is selected in the chosen city by the local committee in close cooperation with the Bureau of Mines officials. An outdoor site such as a stadium or large athletic field is usually preferred; however, an indoor or covered pavilion is also selected to be used in case of inclement weather.

Another function of the local committee is to provide entertainment for the teams, officials, and visitors during the meet - usually a tour of inspection of interesting local industrial plants or mining properties, sightseeing excursions, luncheons, possibly dances, and, as a grand finale, a banquet during which appropriate addresses are delivered by distinguished visitors and prizes are distributed to the winning teams.

Invitations announcing the contest and giving place, dates, and closing date for entries are prepared and sent with entry blanks by the Bureau of Mines to mining companies, organizations, and State departments inviting them to enter teams. The Director of the Bureau of Mines or the Secretary of the Department of Commerce sends invitations to governors of mining States either to be present in person or to send a representative, and to heads of mining departments of Canada and Mexico to send representatives and enter teams if they so desire.

The expenses of sending teams are borne by the company or organization which they represent.

The closing date of entries is usually set 10 days to two weeks prior to the dates of the contest in order that necessary final arrangements can be made and programs prepared. Upon receipt of an entry, general rules, a list of hotels giving rates, and other information such as street maps are forwarded to the team captain through his company or organization official.

Judges for the contest are selected with regard to their proficiency in first aid and their mining experience, as the problems involve mining phraseology; they are invited to participate by the Bureau of Mines. Invitations are addressed to the individual or to an official of his company or organization requesting his services. Invitations are sent only to persons in the mineral industries who have no personal interest in the teams entered in the contest. The expenses of the judges are borne by the company or organization they represent. Acceptances are carefully recorded, and the names of the judges are included in the program.

The rules governing the contest are formulated by Bureau of Mines officials. The "Manual of First-Aid Instruction for Miners," published by the Bureau of Mines in 1921, is the standard used in judging the work of the participants. A typical set of rules follows:

GENERAL RULES

1. The first-aid contest will be held at Columbia Gardens, Butte, Mont., on August 20 and 21, 1928.

2. There will be no limitations as to the number of teams admitted to the contest from any one State, district, company, or organization.

3. The members of all teams must be bona fide employees of the mine or mines, quarry or quarries, smelter or smelters, mill or mills, or petroleum refinery or other branch of the petroleum industry, represented by the team, and may be any underground, or surface workers in or about the mine, smelter, concentrator, metallurgical plant, or petroleum operation, excepting that no physician or trained nurse may be a member of a first-aid team.

4. Any organization, union, club, or local benefit society may enter a team. The members of such team shall be actual members of the said organization and shall be employed in or about a mine, quarry, mill, smelter, or oil plant in the local district covered by the membership of the organization.

5. Each team entering the first-aid contest will be given a number to determine its order of performance and field location. Such numbers will be assigned by lot and given to the teams as they register.

6. Entry shall be submitted in writing or by wire to the Pittsburgh, Pa., office of the Bureau of Mines on or before August 5,1928. On or prior to this date the name of each captain of each contesting team must be submitted. Substitutes will, however, be allowed after August 5, if necessary, by proper statement in writing. No entries will be received after August 5, 1928.

7. Registration of teams will be conducted at the Butte Chamber of Commerce, 62 West Broadway, Butte, Mont., between the hours of 9:00 a.m. and 5:00 p.m., on August 19, 1928. Team registration will be continued at Columbia Gardens, Butte, Mont., beginning at 8:00 a.m. on August 20, until the beginning of the respective contests on that date. Members of the teams, other than captains, will not be required to register.

8. Subject to possible later revision, the first-aid contests will be held between 1:00 p.m. and 5:00 p.m. on Monday and Tuesday, August 20 and 21, 1928.

9. Any team not on hand and ready when the first event for which it is entered is announced, will be disqualified from contesting.

10. Information regarding cups and prizes will be found in the program of the meet which will be given to the teams when they register.

11. The teams winning prizes will be officially announced during the evening of August 22 by a person or persons designated for the purpose.

12. Following the awarding of prizes the captain of each team will be furnished with his team rating.

13. All rules relating to the contests will be rigidly enforced.

RULES GOVERNING FIRST-AID CONTEST

1. A team will be composed of six men, including a captain and a patient.

2. Full team events only will be used.

3. Each team will perform the same number of problems, which will be three or more in number. This, of course, does not prevent the running off of ties between the individual teams concerned, but the points made in events performed to decide a tie shall not be included in the total points in the whole contest.

4. All problems will be worked in marked-off spaces which shall contain only the judges and the contesting teams.

5. The teams will be numbered consecutively, beginning with No. 1, and they must occupy the positions assigned them on the field.

6. At the conclusion of any event, the captain must raise his right hand and announce his team number. The team will remain at its post until relieved by the judges.

7. All teams not performing a problem will be placed in a location where they are unable to obtain information regarding the problem being worked. No persons excepting designated officials will be allowed to communicate with the teams waiting to perform problems or while working problems. Teams which have performed will not be permitted to communicate with teams waiting their turn.

8. Problems will be kept in sealed envelopes and given to teams after they enter marked-off inclosures, envelopes to be opened only on sound of gong.

9. No practicing will be allowed on the field before the beginning of the contest.

10. Material:

(a) Teams must bring their own first-aid material, including bandages, splints, blankets, etc.

(b) Only first-aid material as outlined in the Bureau of Mines "Manual of First-Aid Instruction for Miners" shall be used in the contest. No roller bandages shall be used.

(c) Splints shall not be padded or marked prior to the beginning of any event requiring their use. It will not be a violation of this rule for a team to have on hand padding of suitable dimensions.

(d) A team or team member shall not be allowed to leave the patient in order to obtain material while performing a problem.

11. Timing:

(a) Three minutes will be allowed for reading the problem and assembling first-aid material. This will be indicated by sounding a gong.

(b) At the sounding of the first gong the patient will take his place on the mat.

(c) Unless otherwise specified in the problem the patient will lie on his back, with his head toward the team.

(d) A second gong will be sounded to indicate the time of starting of the problem.

(e) A third gong will be sounded when the time for working the problem is up.

(f) Time consumed in excess of that allowed for the problem will be indicated by a gong at one-minute intervals, until all teams have completed the problem.

(g) In any given event, time will not be taken into consideration unless the team performing exceeds the allotted time, or fails to give treatment promptly.

(h) Teams will be allowed a definite period for removing bandages and leaving field - approximately two minutes.

12. Judging:

(a) Each team as it performs a problem will be rated by a judge, who will mark the score card.

(b) The same number of teams as there are judges will perform at one time.

(c) Judges will receive a score card and a copy of the problem, together with an outline of the correct method of working the problem according to the Bureau of Mines "Manual of First-Aid Instruction for Miners."

(d) Judges should not ask questions or interfere in any way with a team while it is working the problem.

(e) Judges will be required to examine carefully the work done in each event.

(f) Judges should not discuss discounts with a team or within hearing of a team.

(g) When the judges have completed the rating of each team the score cards will be collected by a person or persons designated for this purpose, who in turn will give them to the chief judge.

(h) After the chief judge is satisfied that the score cards are in proper order the cards will be immediately sent to the chief recorder, and scores tabulated. Such scores will be kept confidential by recorders.

13. Ties:

(a) Announcements of ties will be made and decided as soon as possible after the completion of the regular problems.

(b) Ties will be decided by one or more problems if time permits; otherwise, by lot.

14. An event embraces a problem that may call for the treatment of one or more injuries and the handling of the patient.

15. The Bureau of Mines "Manual of First-Aid Instruction for Miners" (1921 edition) is hereby authorized for sole reference and guidance in contest work at this meet. (Note: This manual is a revision of former Bureau of Mines Handbook, "Advanced First-Aid Instruction for Miners," and has been reprinted 16 times, the last time in October, 1928.

16. The use of banners, lettering, or emblems on garments, or marked first-aid boxes and equipment, or use of means of identification of teams other than by numbers officially assigned, will not be permitted on the field.

17. Dress:

(a) Teams performing will wear overalls and jumpers or a similar form of dress, such as a two-piece uniform. Jumpers or coats may be removed provided that a shirt with full-length sleeves is worn.

(b) The patient will be dressed similarly to other team members, except that he will not wear shoes during the time the problem is being worked.

18. Preparation of bandages prior to beginning of a problem will not be permitted, with the exception of cravat bandages, which may be folded.

19. All bandages will be applied over clothing.

20. Infraction of the above rules, if such infractions are not covered in the table of discounts, may result in the disqualification of the team or teams involved.

As the teams, judges, and visitors arrive they are registered by a committee of Bureau of Mines officials. The teams draw for their number and working place on the field and are then turned over to a field committee which assists them in making preliminary preparations and getting their supplies and equipment to the field.

The field is laid out to provide a rectangular working space of 10 by 20 feet for each team, either in parallel or semicircular arrangement, depending upon the shape and size of the field. Each working space is provided with a numbered sign mounted on a stake placed at the center and just back of the border line. The spaces are numbered consecutively and the teams work in spaces corresponding to the number assigned by the registration committee.

The meet officials are a committee of chief judges, supervising judges, team judges or committees of team judges, an announcer, timekeepers, a chief recorder and his assistants, and a managing committee of Bureau of Mines officials.

A committee of chief judges is in complete charge of the contest and is usually composed of three members, one of whom acts as chairman. One member of this committee is generally a high official of the American Red Cross, one member represents the medical profession from the locality where the contest is held, and the third is a high official of some mining company or nationally known organization which does not have a team entered in the contest. This committee assigns the supervising and team judges.

A supervising judge is assigned to a group of two or more teams, depending on the number of teams participating and judges available. These supervising judges are selected from the group of judges and are chosen for their knowledge of first-aid methods and the rules of the contest. Their duties consist of overseeing the work of the team judges and of making decisions on questions which may arise during the working of the problems or which concern the proper discounting of the teams. The supervising judges rotate from group to group in the opposite direction from the team judges. A team judge is assigned to each team. The progressive system of judging is used; that is, the judge for team No. 1 in event No. 1 moves up and judges team No. 2 in event No. 2; likewise, the judge for team No. 20 in event No. 1 would judge team No. 21 in event No. 2. The judge for the last team or the team having the highest team number would revert to team No. 1 for event No. 2, and so on.

The foregoing system is generally employed, especially where there is a scarcity of judges. However, when there is a sufficient number of judges available, teams are judged by subcommittees of judges, composed of two or three members for each team. The progressive system of rotating judges is employed under these conditions also.

This progressive method gives more uniform judging and eliminates the possibility of favoritism being shown to any team.

PROBLEMS

The problems, usually 10 in number, together with outlines for the correct method of working them, are prepared by Bureau of Mines officials. The outlines are for the guidance of the judges to insure uniformity in discounting. The problems are placed in sealed envelopes and no person other than the preparing officials are permitted to see them prior to the contest. The following is a typical problem and outline:

Problem No. 1

Three (3) minutes will be allowed for
reading problem and assembling material.

A patient has the following injuries: Simple fracture of right elbow: compound fracture of left thigh, four (4) inches above the knee, arterial bleeding and bone protruding one (1) inch out of the inside of the thigh; dislocated lower jaw; and a horizontal cut two (2) inches long on the bottom (arch) of the right foot, spurting bright red blood. The patient is unconscious and suffering from shock during the whole problem. Treat and prepare for transportation. Work time ten (10) minutes.

Outline for Working Problem No. 1

1. Arterial bleeding from compound fracture of right thigh and bottom (arch) of left foot. (See pp. 49 to 54 and figs. 10 to 13.)[3]

    (a) Temporary pressure over pressure points on right thigh and back of left knee or thigh.

    (b) Prepare and apply tourniquets at same points.

2. Compound fracture of left thigh 4 inches above the knee. (See pp. 113 to 115 and fig. 49.)

    (a) Straighten and support limb by taking hold of it on either side of fracture.

    (b) Place bandage compress over wound and tie.

    (c) Place triangular bandage over compress and tie. (See pp. 77 to 78 and fig. 23.)

    (d) Splints: 2 of unequal length, 4 inches wide. Pad well, forming arch over fracture.

        1. To reach from armpit to 1 inch below heel.

        2. To reach from crotch to 1 inch below heel

    (e) Bandages (7 cravats).

        1. Above fracture.

        2. Below fracture.

        3. Below knee.

        4. Around ankle.

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3 References are to Manual of First-Aid Instruction for Miners, by a Committee of Surgeons on Standardization of First-Aid: Rev. Ed., Bureau of Mines, 1921, 221 pp.

5. Around chest under arms.

6. Around lower part of chest.

7. Around hips.

(f) Knots to be tied on outer splint.

3. Cut 2 inches long on bottom (arch) of right foot. (See pp. 82 to 83 and fig. 37.)

(a) Apply bandage compress over wound and tie.

(b) Apply cravat bandage over compress and tie.

4. Simple fracture of right elbow. (See p. 103 and fig. 44.)

(a) Support limb by taking hold of it on either side of fracture.

(b) Splints: 2 splints of unequal length 4 inches wide, nailed together to form an "L." Pad well, forming arch over fracture.

1. To reach from armpit to elbow.

2. To reach from elbow to tip of little finger.

(c) Bandages (3 cravats).

1. Around upper end of splint and arm.

2. Around arm and splint above elbow, cross in front of bend of elbow, carry around splint and forearm, then tie.

3. Around wrist and hand, tying on back of hand.

(d) Apply cravat bandage sling. (See p. 41 and fig. 7.)

5. Dislocated lower jaw. (See pp. 91 to 92 and fig. 39.)

(a) Reduce dislocation.

(b) Place folded bandage compress, lead pencil, etc., between teeth.

(c) Bandages (2 cravats.)

1. Center of bandage over front of chin, pass around neck and tie.

2. Center of bandage under chin, pass to top of head and tie.

(d) Tie ends of bandages together on back of head.

(e) Remove wedging object.

6. Shock: Patient unconscious during whole problem. (See pp. 26 to 28.)

(a) Place patient in comfortable position, with head low.

(b) Remove foreign substances from mouth.

(c) Wrap in blankets, clothing, etc.

(d) Pour aromatic ammonia on cloth and let patient inhale fumes.

(e) Place wrapped hot water bottles, hot bricks, etc., around patient under covers.

(f) Rub extremities toward body under covers.

(g) Do not give stimulants by mouth.

Teams should not be penalized for doing more than outlined above unless it is detrimental to the patient.

Conducting the Contest

The contest is conducted during the afternoons of two days, beginning at 1:00 p.m. and lasting until about 5:00 p.m. The teams are required to work five problems each afternoon. Ties, if any, are decided immediately after the second afternoon's events are completed.

Just prior to the beginning of the contest the chief judges call a meeting of all judges at which they are given final instructions as to the standards which govern the contest and the method of scoring. At this meeting the judges are also given the numbers of the teams which they are to judge.

The contest proper is conducted as follows: After the teams and judges have taken their respective places on the field, the announcer calls them to attention and explains the field procedure as set forth in the rules. All announcements are made from the center of the field by the announcer who uses either a megaphone or an amplifying device. It is essential that all announcements be made clearly so that all teams and judges receive instructions and start their work simultaneously.

The problem and score cards for the first event are then distributed by messengers to the judges and at the sound of a gong the judges hand the problem to the team captains. The teams are allowed three minutes to read and discuss the problem and to assemble material which they think necessary for the proper treatment of the patient. After three minutes have elapsed, a second gong is sounded

to signify the beginning of the period allotted for working the problem. This period is usually 10 minutes. Competent timekeepers are at hand and keep careful check on the time, working in cooperation with the announcer who operates the signaling gong. When the allotted working period has elapsed, a third gong is sounded to notify the teams that the time for working the problem has expired and overtime has started. At one-minute intervals, after the working period and until all teams have completed their work, the gong is sounded to keep the judges and teams advised of the length of overtime. At the completion of the work of his team, the captain calls them to attention and notifies the judge that the patient is ready for inspection. The judge carefully checks the work and marks the score card accordingly. The score card is then delivered to the supervising judge for approval and in turn he dispatches the cards for his group by messenger to the chief judges. The chief judges relay them on to the recorders. This procedure, of course, is carried out for each event in the contest.

The score cards are also prepared by Bureau of Mines officials. These are known as discount sheets. A typical set of discounts follows:

TABLE OF DISCOUNTS

Note: No team will be discounted more than once for any one mistake in the same problem where such mistake may be discounted for under more than one of the 14 sections of discounts, except when symptoms are involved. In symptom problems a team may be penalized for failure to explain symptoms and also under the various other sections of discounts when working the problem. Teams will be additionally discounted for repetition of the same mistake in the same problem; for example; two tight bandages, 4 points discount; three granny knots, 3 points discount, etc.

JUDGES DISCOUNT SHEET

1. Not doing most important thing first, such as:

	Discount
(a) Failure to remove patient from dangerous gas, roof, or grounded electric wire, etc. at proper time - - -	6
(b) Failure to insulate oneself when removing patient from live wire -	6
(c) Failure to treat injuries in proper order - - - - -	4
(d) Failure to support fracture previous to application of splints -	4
(e) Treating wrong location of injury, wholly or partially (right for left, arm for forearm, thigh for leg, etc., or other wrong location) each dressing - - - - - - -	4

	Discount
2. Arterial Bleeding:	
(a) Failure to temporarily control hemorrhage previous to application of tourniquet - - - - - - - - - - -	7
(b) Application of tourniquet so as not to stop bleeding -	9
(c) Failure to apply tourniquet (arterial bleeding) - -	10
(d) Failure to apply tourniquet loosely when treating compound fracture not having arterial bleeding - -	6
(e) Tourniquet applied so as to stop bleeding but at wrong point -	4
(f) Tourniquet applied so as to injure patient - - - -	4
(g) Application of tourniquet when not necessary - - -	2
3. Shock:	
(a) Improper position of patient - - - - - - - - - - -	4
(b) Failure to cleanse mouth - - - - - - - - - - - - -	2
(c) Failure to cover patient properly - - - - - - - -	4
(d) Failure to use or improper use of stimulant - - -	4
(e) Failure to use or improper use of heat applications	2
(f) Failure to rub or improper rubbing of extremities-	2
(g) Failure to continue necessary shock treatment throughout problem - - - - - - - - - - - - - - - - -	4
4. Artificial Respiration:	
(a) Failure to place patient in proper position (body, arms, head, etc.) - - - - - - - - - - - - - - - - -	2
(b) Failure to remove foreign substances from mouth- -	2
(c) Failure to see that tongue is in proper position -	2
(d) Failure to loosen tight clothing (neck and waist-line) -	2

	Discount
(e) Improper position of operator's hands - - - - - -	2
(f) Incorrect timing - - - - - - - - - - - - - - - - - -	2
(g) Breaking rhythm in change of operators (for each infraction) -	2
(h) Incorrect position of operator so as to render ineffective artificial respiration - - - - - - - -	10
(i) Incorrect method - - - - - - - - - - - - - - - - - -	10

5. Splints:

(a) Splint improperly applied - - - - - - - - - - - - -	4
(b) Splint improperly padded (no arch at point of fracture, insufficient padding, etc.) - - - - - -	4
(c) Improper splint or marked splint - - - - - - - - -	2
(d) Use of previously padded splint - - - - - - - - -	2

6. Bandaging:

(a) Failure to cover wound entirely - - - - - - - - -	4
(b) Failure to use compress when required - - - - - -	4
(c) Failure to use cravat or triangular bandage or required number of bandages to complete dressing (for each omission) - - - - - - - - - - - - - - - - -	2
(d) Improperly applied compress or bandage (wrong method, location, position of knot, etc.) (Judge describe) -	2
(e) Tight compress or bandage - - - - - - - - - - - - -	2
(f) Loose compress or bandage - - - - - - - - - - - - -	2
(g) Failure to use sling when required - - - - - - - -	2
(h) Failure to use proper kind of sling - - - - - - -	1
(i) Insecure, incomplete, or granny knot - - - - - - -	1

	Discount
7. Failure to be aseptic -	6
8. Unclean first-aid material -	4
9. Transportation:	
(a) Improperly constructed stretcher - - - - - - - - - -	4
(b) Failure to test stretcher before using - - - - - -	4
(c) Failure to command properly - - - - - - - - - - - -	2
(d) Improper position to lift or lower patient - - - -	2
(e) Improper lifting or lowering of patient - - - - -	2
(f) Failure of team to obey command - - - - - - - - - -	2
(g) Improper carrying of patient, such as wrong step, etc. -	2
10. Failure to take from supply base sufficient or proper material to complete problem - - - - - - - - - - - - - - - - -	2
11. Slow and indifferent work:	
(a) Slowness of work. Deduct one point for each minute or fraction thereof consumed over time allotted for working problem - - - - - - - - - - - - - - - - -	1
(b) Lack of attention on part of one or more team members -	2
(c) Lack of neatness - for each bandage, splint, etc. that is not neat -	1
(d) Delayed treatment (slowness in getting started, controlling arterial bleeding, starting artificial respiration, treating for shock, etc.) - - - - - -	2
12. Rough or awkward handling of patient - - - - - - - - - - - -	4
13. Assistance lent by patient (physical or verbal) - - - - -	2
14. Failure to explain symptoms (symptom problems only) for each injury team fails to explain - - - - - - - - - - - - -	4
Total	200

Recorder________________________ Judge________________________

The discounts marked by the judges are totaled by the recorders, checked by the chief recorder, and recorded on specially prepared recording sheets. The recorders carry progressive totals on the recording as the events are run off so that very shortly after the final event they are able to announce any ties which may occur, thus saving considerable time in having tied teams work an extra problem to decide the ties. The team making the highest general average is declared the winner of the contest. A typical discount record is as follows:

Team No. 3

Event No.	1	2	3	4	5	6	7	8	9	10
Discount	7	6	20	14	2	1	9	6	6	1
Total discount		13	33	47	49	50	59	65	71	72

General Average - 96.4 per cent

In order to arrive at the general average the following method is employed:

E = Number of events,
TPD = total possible discounts for each event,
TD = total discounts received by team.

Then: $$100 \text{ per cent} = \frac{TD}{E \times TPD} = \text{General Average}$$

Thus: $$100 \text{ per cent} = \frac{72}{2000} = 96.4 \text{ per cent}$$

The teams are required to remain on the field after completing the final event of the contest so as to be available to work an extra problem to decide ties if any should occur.

The tie problem is conducted in the same manner as are the regular events, with the exception that two or more judges observe the work of each team. The plus and minus system of scoring is used in the extra event. After the teams have completed their work the judges make a careful inspection and decide which of the teams has done the best work. They report their decision to the chief judges, who in turn notify the chief recorder. The team which in the judges' opinion is the better of two or more tied teams is given a plus mark after its general average; the second best is given a minus mark; and should a third team have tied a double minus is scored. This plus or minus system, of course, can not very well be employed if more than three teams are tied for any one place. In such a case it is better to employ the discount system and rate the teams in accordance with the number of discounts.

The teams winning first, second, and third places are given prizes. These prizes are donated by the Bureau of Mines, mining companies, mining organizations, and manufacturers of mining equipment. The condition of award is stipulated by the donor. To illustrate this point, the following list of prizes donated for the contest held at Butte, Mont., on August 20 and 21, 1928, is given:

PRIZES FOR FIRST-AID TEAMS, AND CONDITIONS OF AWARD

The Congressional bronze medallion, awarded by act of Congress, for permanent possession of the first-aid team winning first place in the International First-Aid Contest.

Silver cup, presented by Coal Age to the first-aid team winning first place, and to be held until the next national or international contest.

Silver cup, presented by the Illinois Coal Operators' Association, Central Illinois Coal Operators' Association, Fifth and Ninth Districts Coal Operators' Association of Illinois, and United Mine Workers of America, District 12, to the first-aid team winning first place - cup to be held until the next national or international contest.

Silver cup, presented by the National Coal Association awarded to the first-aid team winning first place, for permanent possession of the team.

Silver cup, presented by the Rocky Mountain Coal Mining Institute to the first-aid team, representing a coal-mining company, a coal miners' organization, or a group of individual coal miners, making the highest score from the Rocky Mountain States of Colorado, Idaho, Montana, New Mexico, Utah, and Wyoming; the cup to be held until the next national or international contest.

Silver cup, presented by the Mine Operators of Butte, Mont., to the first-aid team from outside of Montana making the highest score, for permanent possession of the team.

Six wrist watches, presented by the Rocky Mountain Coal Mining Institute to the individual team members of the team winning the silver cup presented by the Rocky Mountain Coal Mining Institute.

Gold, silver, and bronze medals of the National Safety Council presented to each member of first, second, and third winning teams, respectively, in the international contest.

Bronze medals of the American Red Cross awarded to each member of the team winning first place in the international contest.

Prize certificates of the American Red Cross awarded to members of teams winning second and third place.

Banners to first, second, and third place teams.

Banner to the team having the highest score from each State represented in the contest.

These prizes are presented by one of the Bureau of Mines officials to the teams at the close of the banquet arranged by the local committee. In some instances, a representative of the donor of a certain prize is in attendance and presents that particular prize, felicitating the winning team in the donor's name.

The cost of conducting a national or international contest is nominal in consideration of the stimulating effect on the industry as a whole and on the individual participants in the contest. The total expenditure for the contest held at Pittsburgh, Pa., in September, 1927, amounted to about $3,000, divided as follows:

Printing[4], postage, and stationary	$750
Badges, banners, etc.	250
Rent and marking of field	200
Amplifiers for field announcements	300
Banquet (including rent of banquet hall)	1,500
Total	$3,000

The United States Bureau of Mines considers the holding of these contests to be one of its principal functions. For about two months prior to the date of the contest one of the bureau officials devotes his entire time to making the preliminary arrangements. To insure a successful contest this official must execute these preliminary arrangements with utmost care and close attention to details.

Much interest has been shown in the national or international contests by the mining, quarrying, and petroleum industries in the United States. Unquestionably these meets have real value in stimulating safety educational work and promoting accident prevention in the mineral industries. This fact is evidenced by the growing interest in local and State-wide contests which serve as eliminations in choosing teams to compete in the national or international contest. Other indications of interest are the enthusiasm with which the competing teams enter into the eliminations and their eagerness to win a chance to represent their company or State at the national or international contest. The Bureau of Mines each year lends its assistance and cooperation in promoting local contests, with the hope of making the effect of the national or international meet as far reaching as possible; it is believed that this end has been accomplished to no small degree.

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4 Includes the printing of a 62-page illustrated program-booklet, $5\frac{1}{2}$ by $8\frac{3}{4}$ inches in size.

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Circular No. 6091
December, 1928.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

RECOMMENDATIONS OF THE BUREAU OF MINES ON CERTAIN QUESTIONS OF MINE SAFETY[1]

by

The Mine Safety Board[2]

Introduction

Mining men and State officials in their efforts to make mining safer are confronted from time to time with various complicated questions. In recent years these questions have tended to increase with the use of mechanical appliances. Twenty-five years ago electricity had hardly been used in mines. Today there is practically no other means of transmitting energy employed in American mines, except in metal mines where compressed air is used for drilling and small portable hoists. In coal mines there has been a great increase in mechanization and a tendency to concentrate the mining operation, which has resulted in attendant difficulties of ventilation and intensified the danger of coal-dust in bituminous and subbituminous mines.

The answers to the questions which arise are not always obvious, as is shown by the fact that even able, experienced men differ in their opinions of the best way to overcome a particular mining hazard. The difficulty of solving the problems is also demonstrated by the varying provisions in mine safety rules, both in official regulations and in the rules of those mining companies who are endeavoring to do more than follow the letter of the law. Such differences of opinion on the best way of meeting a difficult situation are often found within the same mining organization, and so it has been in the Bureau of Mines.

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1 The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"

2 G. S. Rice, chief mining engineer, chairman,
O. P Hood, chief engineer, mechanical division,
R. R. Sayers, chief surgeon,
D. Harrington, chief engineer, safety division,
C. W. Wright, chief engineer, mining division.

In order to reduce such differences of opinion and to obtain a generally acceptable decision on any question; a mine safety board was established by the Director of the Bureau of Mines,

> "to consider questions arising within any divisions of the bureau that require a definition of the bureau's collective opinion as to safety practices, safety devices, or safety methods for underground operations or open-pit mining. . . . . <u>The approved decisions shall form the basis of teaching and policy for the bureau.</u>"

The decisions so far made for issuance publicly relate chiefly to questions on which there have been the greatest differences of opinion and to the best method of meeting certain special or new dangers. Other decisions will be rendered from time to time. Bureau recommendations on general mine-safety problems have already been issued on many questions, the answers to which are obvious or on which there is practical agreement among mine-safety men. These are contained in numerous publications of the bureau, and those relating to coal-mine safety are discussed in a handbook entitled "Safety in Coal Mining."[3]

All but the last of the following 10 decisions have already been published, but in response to requests they are now issued in assembled form with explanation. Most of them apply to coal mining, but numbers 7, 8, and 10 may also apply to metal and other kinds of underground mining. All of the 10 decisions except 2, 5, and 6 relate directly or indirectly to mine ventilation.

The wording of the decisions makes their application largely self-evident, but a certain amount of additional explanation is here given as to the detailed purposes and reasons for which they have been formulated. All the features covered by the decisions arose in the study of reports made for and by the bureau, on mine fires, explosions, and general accidents in mines, and it was found as previously indicated that the different members of the bureau staff were not always in agreement as to the best method to recommend for technical handling of a specific complicated problem. Such questions are referred to the Mine Safety Board and an attempt is made to reach a common opinion.

Where decisions are made they form the basis of the recommendations made by the bureau to those mine managements seeking to follow the best practice in attaining the greatest degree of safety.

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3 G. S. Rice, Safety in Coal Mining: Bull. 277, Bureau of Mines, 1928, 141 pp.

The decisions will be taken up in their order.

Decision 1, relating to miners' lamps in coal mines

"The Bureau of Mines recommends:

(a) In all coal mines the portable lamps for illumination be permissible, portable, electric mine lamps; and also
(b) In places where fire damp or black damp is liable to be encountered, a permissible magnetically-locked flame safety lamp for gas detection, or equivalent permissible device, be supplied to at least one experienced employee in each such place; and
(c) Any employee before being supplied with a permissible flame safety lamp be examined by a competent official of the mine to assure the man's ability to detect gas; and
(d) All coal mines whether classed as non-gassy or gassy in any part, be supplied with magnetically-locked, permissible, flame safety lamps, properly maintained and in sufficient number for all inspection purposes."

These recommendations were made for the following reasons:

First, miners' electric lamps have been so improved that it is no longer a hardship in coal mining to use a portable permissible electric lamp; in fact it is quite the reverse. All open lamps that may cause fires or explosions should be eliminated.

Second, since no approved electric lamp shows the presence of methane or indicates oxygen deficiency, one experienced employee in every place where such conditions are liable to be found should be provided with a permissible flame safety lamp, or equivalent permissible device, to be used for testing.

Third, that although a permissible flame safety lamp is safe is properly assembled and used, there is a possibility of its being a souce of ignition of fire damp if the lamp is illegally opened in the mine or is dropped and the glass broken or if the lamp is struck by a sharp point. Accordingly the use of the permissible flame safety lamps is limited to testing in the hands of competent and experienced employees who can determine with accuracy and safety the percentage of methane in the air in excess of $1\frac{1}{2}$ or 2 per cent.

Other underground employees would under this decision be provided with portable permissible electric lamps giving an excellent steady light; the good illumination would tend to prevent accidents from falls and other hazards, and would avoid the danger of igniting gas.

Decision No. 2, relating to the kind of explosives to use in coal mining.

> "In the interest of safety the Bureau of Mines recommends that for blasting in coal mines, permissible explosives, fired electrically, be exclusively used; and that as an aid to blasting, all coal which is feasible to cut, should be cut or sheared."

The foregoing decision has reference to the character of the explosives employed for blasting in coal mines. It does not preclude the use also of methods, devices, and appliances for blasting in coal mines, which have been approved by the Bureau of Mines and placed on its permissible lists.

Nonpermissible explosives like black blasting powder, dynamite, and special explosives that will not pass the bureau's tests for permissibility, readily ignite fire damp and coal-dust, and have been the cause of countless explosions. Complaint is sometimes made that permissible explosives are not efficient because they can not be efficiently used in "blasting off the solid." This practice, however, is a highly dangerous one, and should not be used at the expense of safety.

Where coal is properly undercut, sheared, or overcut, blasting can be done efficiently and safely with permissible explosive. The design of coal-cutting machinery has so improved that practically any condition in mining can be met by selection of a suitable cutter and a suitable mining method. At present three-fourths of the coal in the United States is cut by machines. It is estimated that in some coal beds blasting with permissible explosives following cutting makes a few per cent more screenings than if black blasting powder is employed. Even if the estimate is admitted to be correct the bureau believes that no operator is justified in taking the chances of an explosion disaster by using a nonpermissible explosive.

Decision No. 3, defining what the Mine Safety Board considers to constitute a nongassy, a slightly gassy, and a gassy coal mine.

The Bureau of Mines believes that all coal mines are potentially gassy; but for purposes of administration in respect to prevention of explosions and fires, the Bureau recommends the following classification:

Class 1 Coal Mine: a practically non-gassy mine in which inflammable gas in excess of 0.05 per cent can not be found by systematic search.

Class 2 Coal Mine: a slightly gassy mine in which

(a) inflammable gas has been found* but in amount less than 2 per cent in still air in any active or unsealed-abandoned workings; or

(b) inflammable gas can be found, but in amount less than 4 per cent, in some place from which the ventilating current has been shut off for a period of one hour; or

(c) inflammable gas can be found** but in amount less than 1/4 per cent, in a split*** of the ventilating current; or

(d) inflammable gas enters a split*** of ventilating current at a rate**** of not more than 25 cubic feet per minute.

Class 3 Coal Mine: a gassy mine in which inflammable gas is found in amount greater than specified for a Class 2 Coal Mine.

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* By employing an approved flame safety lamp, with flame drawn low, or by employing an approved gas detector, or by sampling and analysis with an approved gas analytical apparatus.

** By sampling and analysis with an approved gas analytical apparatus, or by employing an approved gas detector.

*** If but one continuous ventilating current is employed in a mine this shall be considered a "split" for the purpose of this definition.

**** Determined by sampling, analysis, and ventilating-current measurement.

General Notes Regarding Decision No. 3

The inflammable gas found in coal mines is, with rare exceptions, methane. In coal-mining fields where natural gas is found in lower geologic horizons by deep wells which pass through or near by the coal mines, there have been rare instances of a leakage from the well. Natural gas is chiefly methane - almost always more than 85 per cent is methane - but it usually contains ethane, propane, and traces of butane. Therefore if the latter gases are found in mine air, it is an indication of leakage. The lower limit of explosibility of methane-air mixture when there is turbulance is 5 per cent and of natural-gas-air mixtures with about 10 per cent ethane and associated hydrocarbon gases is 4.6 per cent. The limit therefore varies with the character of mixture.

To determine the proper classification of a coal mine, it is advisable that systematic testing and sampling be done at least three times in a period of not less than 72 hours. All tests and samples of the mine air, except one, must show

an inflammable-gas content less than the maximum limit of the class to which the mine is assigned. In other words, a tolerance of one test or analysis may be permitted to provide for a mistake or a very exceptional occurrence.

When a new mine is being opened in a coal field where existing mines are generally gassy, it is common sense to assume that similar conditions will be found in the new mine; the development and equipment of the mines should be based upon the expectation that it will be assigned to Class 3.

There is no more disputed question than that covered by this decision as to what constitutes a gassy (or gaseous[4]) mine. Only a few State regulations give any specific directions for determination of gassiness other than that of whether or not approved flame safety lamps are required. A coal mine is popularly spoken of as a "closed-light" mine or an "open-light" mine.

Such a method of rating a mine as gassy is not satisfactory partly because there is such a great difference in other requirements - in ventilation, in use of electricity, etc. Also it tends to prevent the adoption of the "closed lamp" by many mine operators who do not like to admit that their respective mines are gassy; although this is not a good reason why the operator should not take maximum precautions, it is a practical consideration. The bureau's plan in this decision would get away from the indefiniteness and confusion by specifying in precise terms what it designates as a "nongassy," a "slightly gassy," and a "gassy" mine. The bureau's specifications are founded on a study of thousands of analyses of samples of mine air submitted to the Bureau of Mines laboratory at Pittsburgh.

Decision No. 4, relating to auxiliary fans or blowers in coal mines.

> In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that auxiliary fans or blowers should not be used in coal mines as a substitute for methods of regular and continuous coursing of the air to every face of the mine.

The reason for this decision is the widespread recent use of auxiliary blowers, which are nearly always electrically driven in the United States, as a substitute for the regular coursing of the air by frequent ventilation connections and by use of line-brattices. There is great danger of fire damp accumulating by recirculation of the air, and of igniting it by electrical spark. Further, the auxiliary fan is usually intermittantly used and bodies of fire damp collect.[5] Use of the fan has resulted in a considerable number of explosion disasters.

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4 Although the word "gaseous" is most generally used in the United States, "gassy" is considered by the bureau as more accurate in meaning. Literally a "gaseous mine" would be one not mining solids. A "gassy mine" is one in which the presence of gas is incidental to the mining operation.

5 The only justification for its use in a properly ventilated coal mine is for emergency work, as in driving a cross-heading in rock to make a connection with distant workings, and where it is too far to carry the air properly by a line brattice. In such a case the auxiliary fan should be operated continuously 24 hours in the day, and the fan and face of the heading should be frequently inspected. A compressed-air driven fan is recommended. If an electrically driven fan is employed, especial attention should be given to thorough insulation of the wiring and fireproofing in the vicinity to prevent the possibility of a mine fire starting from electrical breakdown or overheating of bearings.

Decision No. 5, relating to the prevention of coal-dust explosions by rock-dusting.

To prevent the propagation of mine explosions, the Bureau of Mines, Department of Commerce, recommends rock-dusting all coal mines, except anthracite mines, in every part, whether in damp or dry condition. It also recommends that rock-dust barriers be used to sectionalize the mine as additional defense; but these should not be regarded as a substitute for generalized rock-dusting.

NOTE: For detailed specifications as to the kind of rock-dust, amount to use, where to be applied, and method of sampling and testing, see Bureau of Mines Serial 2606 and American Engineering Standards Committee "Recommended American Practice for Rock-Dusting Coal Mines" quoted in Bureau of Mines Information Circular No. 6030.

The rock-dusting method[6] of preventing coal-dust explosions has now been accepted in principle by all of the chief coal-mining countries throughout the world. It was recommended after exhaustive testing in the Bureau of Mines experimental mine in 1913. The method was officially approved by France about 1917. It was officially required by Great Britain in 1921, and in Germany in 1926.

Decision No. 6, relating to sealing all parts of a coal mine which can not be kept well ventilated and inspected.

In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that in coal mines all entries, rooms, panels, or sections that can not be kept well ventilated throughout or can not be inspected regularly and thoroughly, or that are not being used for coursing the air, travel, haulage, or the extraction of coal, be sealed by strong fireproof stoppings.

In the past the question of sealing has been a much disputed one among mining men. Some have considered that it was highly dangerous to inclose areas in a mine which might fill with a body of gas. The bureau agrees with this point of view, unless the stoppings are strong and fireproof; and by strength is meant strength sufficient to hold the stoppings in place if there should be a heavy fall of roof in an empty or partly empty goaf; suddenly compressing the gas or gas and air mixture.

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6 The suggested use of bringing in inert dust to neutralize the coal-dust was proposed by William Garforth in 1891, and testing began under his direction in 1908 at the Altofts Colliery, Yorkshire, England. In the United States, testing was begun under the Technologic Branch of the U. S. Geological Survey (later the Bureau of Mines) by G. S. Rice and associates in 1909.

On the other hand the engineers of the bureau find from extensive experience that large room-and-pillar mine in which the pillars are either not extracted at all or not extracted for a long period. The old areas are not generally well ventilated and often can not be inspected because of danger of falls, and that the lack of ventilation is inevitable from the enormous territory which may be opened up. Also these regions act as accumulating places for dangerous dust as well as gas.

The bureau believes that the ideal system of coal mining is to take out only a small percentage of coal on the advance, generally less than 20 per cent, and then to extract the pillars promptly on a systematic line of retreat for the whole mine or for a large panel which may be considered equivalent to longwall retreating. Under such conditions there should be no need of sealing extensive areas of open unused workings.

Decision No. 7, relating to the carrying of "intake" and "return" air currents in separate shafts, slopes, or drifts.

In the interest of safety, the Bureau of Mines, Department of Commerce, recommends:

1. That the main intake and main return air currents in mines be in separate shafts, slopes or drifts.

2. That the main intake shaft lining be of fireproof construction, and there be a minimum amount of inflammable material in or adjacent to the shaft.

The recommendations in this decision are applicable to any kind of underground mining. Engineers of the bureau engaged in mine recovery operations during or following fires in coal and metal mines have experienced great difficulty in controlling ventilation and coping with hazardous conditions caused by placing of the "intake" and "return" currents separated only by a partition, in the same mine opening. Even if the partition is fireproof, the smoke and fumes at the bottom of the shaft or slope will almost inevitably work around into both compartments. Also entrance to either compartment at the surface may be made impossible by flame or smoke.

If a strong explosion in a coal mine reaches a shaft in which a partition separates the intake and the return currents, the partition, even though made of concrete, is sometimes blown out because of the unbalanced explosion pressures in the separated compartments of the shaft.

Generally the two compartments in the same mine opening have been used because they were convenient and possibly reduced the initial expense of opening the mine, but such considerations should have no place in the development of a mine, the lifetime of which may be many years.

A fireproof lining in the main intake shaft is recommended to provide a safe means of exit in the event of an explosion or fire. In the greatest mine fire disaster that has occurred in this country, in which 259 men were killed, the mine fire ignited the lining of the intake shaft as well as of the return shaft and thus prevented the escape of the men.

The best practice today is to have at least three shafts with fireproof lining and to have the main hoisting shaft nearly neutral, with just enough of a fresh-air intake split to keep it properly ventilated.

Decision No. 8, relating to definitions used in coal-mine ventilation regulations, but which may also be applied to ventilation in metal and other mines.

The Bureau of Mines, Department of Commerce, recommends that in coal-mine ventilation the following definitions be used:

1. The term "intake air" and the term "return air" without qualifying adjectives shall be used only to define mechanical movement of the air respectively in an inward or outward direction with reference to the mine as a whole or to any one group of workings.

2. When health and safety are concerned, the term "pure intake air" shall mean:

(a) Air which has not passed through or by any active workings, and (or)

(b) Air which has not passed through or by any inactive workings, unless these are effectively sealed, and

(c) Air which is free from poisonous gas and by analysis contains not less than 20 per cent oxygen (dry basis) and not over 0.05 per cent of inflammable gas.

In the State mining codes there is much ambiguity as to the meaning of different mining terms. Therefore, as a prerequisite to the formulation of better codes, it is advisable to have specific terms.

Decision No. 9, relating to the quantity and quality of air to be furnished in ventilating coal mines.

The Bureau of Mines, Department of Commerce, recommends in coal-mine ventilation practice the following specifications as to unit quantity and quality of air:

1. The quantity in cubic feet of pure intake air flowing per minute in any ventilating split shall be at least equal to 100 times the number of men in that split.

2. The quantity of air entering each unsealed place shall be at least 200 cubic feet per minute and as much more as may be necessary to properly dilute and carry away inflammable or harmful gases which may be present.

3. The air shall be made to circulate continuously to the face in every unsealed place into which an appreciable amount of methane enters.

4. The air in any unsealed place shall be considered unfit for men if it shall be found to contain less than 19 per cent oxygen (dry basis), more than 1 per cent carbon dioxide or a harmful amount of poisonous gas.

5. If the air in any unsealed place, when sampled or tested in any part of that place not nearer than four feet from the face and ten inches from the roof, shall be found to contain:

(a) more than $1\frac{1}{2}$ per cent of inflammable gas, the place shall be considered to be in hazardous condition and require improved ventilation, and

(b) if more than $2\frac{1}{2}$ per cent of inflammable gas is found, the place shall be considered dangerous, and only men who have been officially designated to improve the ventilation and are properly protected shall remain in or enter said place.

6. If the air in the split which ventilates any group of workings contains more than $1\frac{1}{2}$ per cent of inflammable gas, these workings shall be considered to be in a dangerous condition and only men who have been officially designated to improve the ventilation and are properly protected, shall remain in or enter said workings.

This decision contains provisions for the quantity of air which must be furnished to each and every man in a mine. First, it recommends that the usual minimum of 100 cubic feet of air per minute shall be furnished each man in the mine, but also that the measurement of the air be made in each ventilating split and not at the foot of the shaft or entrance to the mine or an exit from the mine, as it has been found that in some mines there is a leakage of from 50 to 75 per cent or more between the fan and the working faces.

The second provision is to take care of the condition where workings are left open, and to call for a ventilation by the same amount of air as provided in the active working places. To obviate the need for this additional ventilation, the remedy would be to seal off unused workings as recommended under Decision 6.

The third provision is to insure that in a gassy place the ventilation will be carried into the face of every active and inactive open working place by means of crosscuts and line-brattices beyond the last open crosscut and thus will prevent accumulations of fire damp.

The fourth provision refers to the quantity of the air; that is, if the ventilation called for in provisions one and two is not adequate, additional quantities of air should be furnished to the respective places.

The fifth provision is to define the minimum amount of inflammable gas which may be considered to be a dangerous hazard in a working place; another specification defines the limiting percentage of inflammable gas in places from which the men should be withdrawn.

The sixth provision concerns the limiting percentage of inflammable gas in a ventilating split that is so dangerous as to require the withdrawal of the men from the workings.

Decision No. 10, relating to ways of escaping from a mine

The Bureau of Mines, Department of Commerce, in the interest of safety in all underground mines, recommends:

1. That every underground mine shall have two or more ways of escape to the surface, so arranged and equipped that men can escape quickly.

2. Such ways of escape shall be so separated by at least 50 feet of natural ground throughout their length that damage to one from any source shall not thereby lessen the effectiveness of the other as a means of escape.

3. (a) Where the way of escape is a shaft which is steeper than 45 degrees from the horizontal, it shall have incombustible walls or lining and contain no fire hazard from the surface to the lowest level.

(b) Where the way of escape is a drift or slope which is inclined less than 45 degrees from the horizontal, the incombustible walls, or lining, and freedom from fire hazard shall extend at least 200 feet from the entrance.

4. Where but one way of escape has incombustible walls or lining, it shall be the normal intake airway.

5. Not more than 10 men shall be employed in any part of a mine on any one shift until a second way of escape from that part has been provided.

Decision 10 is intended to apply to any kind of underground mine.

The first provision is one which is to be found in practically all State mining codes, except that as a rule requirements are not made for the quick escape of men, aside from the satisfactory means of escape. Since the establishment of the Bureau of Mines there have been numerous accidents in places from which men were unable to escape by satisfactory means because there were not adequate arrangements for their getting out quickly, as by hoist in a deep shaft.

The second provision is to establish a minimum distance between ways of escape to insure that a fire or explosion which blocks one way would not at the same time render the other means of escape difficult or impossible of access.

The third provision relates to making fireproof the shaft, drift, or slope used as an escapeway.

The fourth provision is to insure that where there is only one way of escape that is fireproofed, it shall be used as the normal intake airway. This clause is also covered in a different manner by the second clause in Decision 7.

The fifth provision is to prevent the employing of any considerable group of men in any part of any mine where there are not two ways of escape, and limits the group to 10 men on any one shift exposed to a hazard, until a second way shall have been made by sinking shafts or slopes, or driving drifts or crosscuts from the surface or from other workings.

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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

THE CLASSIFICATION OF NORTH AMERICAN COALS[1]

By A. C. Fieldner[2]

INTRODUCTION

Two years ago at the time of the First International Conference on Bituminous Coal, a meeting of representatives of various professional societies and of industrial, educational, and governmental organizations was held in Pittsburgh to consider what action, if any, should be taken on the classification of North American coals. This meeting was called by the American Engineering Standards Association because a system for the use classification of coal, proposed by Geo. H. Ashley[3], had been referred to the Association by the Coal Mining Institute of America. The meeting was well attended and was definitely in favor of taking up the whole question of both scientific and use classification of coals, including all the various ranks from lignite to anthracite. The American Society for Testing Materials was recommended as the sponsor organization to take charge of the work and organize the sectional committee, according to the rules of the American Engineering Standards Association. These rules provide that: "The personnel and composition of each sectional committee shall be authoritative and adequately representative of the various interests concerned in the standard or group of standards for the formulation of which the sectional committee is responsible."

Following this meeting the American Society for Testing Materials proceeded with the organization of the committee. Invitations to appoint representatives were sent to the various trade organizations interested in the production, distribution, and consumption of coal, and also to professional, scientific and technical societies and to governmental organizations interested in coal classification. The organization meeting of the committee was held in Philadelphis on June 10, 1927. Officers were elected, regulations adopted, and general plans for carrying out the work were outlined.

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1 Paper presented at Second International Conference on Bituminous Coal, held at Carnegie Institute of Technology, Pittsburgh, Pa., Nov. 19-24, 1928. The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by Permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"

2 Chief chemist, U. S. Bureau of Mines; Chairman, American Engineering Standards Sectional Committee on the Classification of Coal.

3 Ashley, Geo. H., "A practical classification of coals:" Proc. Coal Min. Inst. Am., 1923, pp. 29-36; "A use classification of coal:" Trans. Am. Inst. Min. and Met. Eng., 1919, pp. 1129-1141.

Following this organization meeting, the membership of the sectional committee was completed. The total membership of 28 consisted of eight producers, two distributors, nine consumers, and nine members representing general and scientific interests.

Obviously, a committee of 28 members is too large for effective operation. Therefore, three technical committees of 10 to 12 members each were organized; these are on Scientific Classification, H. J. Rose, Chairman; Use Classification, W. H. Fulweiler, Chairman; and Marketing Practice, F. R. Wadleigh, Chairman. The Technical Committee on Scientific Classification was requested to formulate a system of coal classification based on chemical and physical properties of the coal and with reference to origin and constitution. The Technical Committee on Use Classification was charged with developing a system of classification, if possible based primarily on the uses of coal and commercial practice - this system to be correlated with the scientific system as far as possible and desirable. The Technical Committee on Marketing Practice was formed to collect and collate information on commercial practice for the benefit of the other two committees.

The first meetings of the technical committees were held on November 17, 1927, and the first informal progress reports were submitted to the sectional committee at the annual meeting held on March 28, 1928. These reports showed that each committee had made a satisfactory beginning in planning programs and assembling necessary data for carrying out their work. It is believed that a brief review of this first year's work will be of interest to this International Conference and may arouse discussion and possibly pave the way for cooperation in an international system of classification.

WORK OF THE TECHNICAL COMMITTEE ON SCIENTIFIC CLASSIFICATION

The Technical Committee on Scientific Classification accepted the instructions of the executive committee and agreed that a scientific system for the classification of coal should be developed primarily on the basis of chemical, physical, and geological considerations. The work of the committee was organized under the following subcommittees:

Subcommittee I - On nature, location, and mode of occurrence of types of American coals. M. R. Campbell, Chairman.

Subcommittee II - On Origin and composition of coal, and methods of analysis. A. C. Fieldner, Chairman.

Subcommittee III - On present and proposed systems of coal classification. H. J. Rose, Chairman.

Mr. Campbell[4], Chairman of Subcommittee I, presented a comprehensive description of the U. S. Geological Survey basis of classification of coal by ranks at the first international conference in 1926. This system of classification by rank recognizes the various stages through which coaly matter passes in its progressive transformation from peat to anthracite. Unfortunately, nature has not set up any definite subdivisions in this scale; therefore, the limits of the different ranks are arbitrary, and overlapping of properties can not be avoided. However, Campbell has given extended study to this scheme of classification and has developed a general plan of classification which has been used by the U. S. Geological Survey and the U. S. Bureau of Mines for coals of the United States. This scale includes the following nine classes or ranks of coal and allied mineral substances:

Table 1.- List of classes or ranks of coal and allied substances.

Class or rank	Equivalent term in present U. S. Geological Survey classification.
A	Peat
B	Lignite
C	Subbituminous
D	Bituminous, low rank
E	Bituminous, high rank
F	Semibituminous
G	Semianthracite
H	Anthracite
I	Superanthracite

The application of chemical and physical criteria to these classes will require extended work by the committee. Proximate and ultimate analyses, calorific values, and physical properties are all of importance. For a beginning, Campbell has confined himself to the proximate analysis and the calorific value of the dry ash-free coal, and to certain physical properties, such as the tendency to slack on exposure to the atmosphere. Table 2 gives a summary of these criteria.

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4 Campbell, Marius R., "American coal supply: Its quantity, quality, and distribution:" Proc. Internat. Conf. on Bit. Coal, Carnegie Institute of Technology, 1926, pp. 5-64.

Table 2.- Analytical limits and physical criteria for various ranks of coal.

Class or Rank	Proximate analysis percentage in ash-free coal: Moist-ure	Vol. matter	Fixed carbon	Calorific value of ash-free coal, B.t.u.	Physical properties and occurrence
A	90-80	- -	- -	- -	Peat.
B	50-32	25-30	28-37	6,400-8,300	Slacks freely on weathering; non-coking; northern part of Great Plains and Gulf Coastal area.
C	32-12	32-38	36-50	8,550-11,800	Slacks considerably on weathering; non-coking; Western States and possibly certain coal fields, Iowa, Illinois, Missouri, western Kentucky, and Indiana.
D	12-5	39-42	49-53	12,000-13,600	Slight or no slacking on weathering; may be coking; all coal-bearing States except the Dakotas.
E	5-35	40-22	55-75	14,000-15,000	No slacking properties; often coking; most abundant in Appalachian field, but also found in most coal-bearing States.
F	26-23	23-15	74-82	15,200-15,300	Friable; coking; nearly smokeless; central Pennsylvania; New River-Pocahontas field; Fort Smith field of Arkansas and Oklahoma.
G	Fuel ratio (F.C/V.M.) from 4.0 to 10.0				Less hard and less lustrous than typical anthracite; near Lykens, Bernice, and Carbondale in Pennsylvania; Meadow Branch field of West Virginia; and Valley field of Virginia.
H	All Pennsylvania anthracite with fuel ratio over 10.0				Pennsylvania anthracite.
I					Resembles graphite; Rhode Island and southern Massachusetts. Local deposits due to metamorphism caused by volcanic dikes and sills.

The foregoing criteria of classes of coal in the rank scale apply to the ordinary ulmic or woody type of coals. Similar criteria will be worked out for cannel and boghead coals. Three types of coal are recognized, namely: (1) Woody, xyloid, ulmic, or humic coals; (2) canneloid or spore coals; and (3) boghead or algal coals. The type represents the nature of the original coal-forming vegetation, and the rank represents the degree of transformation or metamorphism.

Subcommittee II, on origin, composition, and methods of analysis, is the authority on testing methods, both in describing existing methods and in developing new methods. This committee will be the source of information on the interpretation of old analyses, and will advise on what properties determinations can be made. Existing analytical data will be assembled by this committee. A preliminary report has been made which gives the probable errors and limits of accuracy of the American Society for Testing Materials, the standard methods of analysis, and comments on the effect of changes made from time to time in the standard methods. Experiments are now in progress on the development of an accelerated slacking test for low-rank coals and lignites. These coals usually have a high moisture content and disintegrate or slack after mining. The slacking tendency has been considered characteristic of subbituminous coals and lignite in the U. S. Geological Survey method of classification.

Briefly, the slacking test consists of air-drying a 1,000-gram sample of 1 to 2 inch lumps at 30 to 35° C. for 24 hours, and then immersing the lumps in water for one hour; the water is then drained off, and the sample is again air-dried for 24 hours. The amount of disintegration is determined by sieving on an 8-in. wire-mesh sieve with $\frac{1}{4}$-in. square openings, and weighting the undersize and oversize. The percentage of undersize is a measure of the slacking characteristics of the coal. Results of preliminary tests are promising; a sample of Texas lignite gave 97 per cent fines; a Wyoming subbituminous coal, 84 per cent; an Iowa low-rank bituminous, 24 per cent; and high-rank bituminous coals, which are known not to slack, gave 3 to 10 per cent fines.

One of the most important problems facing the analytical committee is the question of whether to use for classification the simple, dry, ash-free analytical values as ordinarily determined in commercial coal analyses, or the "unit" values as proposed by Parr. Strict accuracy also demands special correction of the hydrogen and carbon determinations to eliminate that part of these elements which is derived from water of constitution in shale or clay and from carbonates. Tideswell and Wheeler[5], and also Seyler[6], favor such corrections. Our committee recognizes the theoretical justification in favor of the corrections, but it also appreciates the practical difficulties of getting commercial laboratories to adopt the more complicated procedures. The committee is therefore approaching this question with an open mind, and proposes to make a thorough investigatien of the problem.

The suggestion has been made that the inorganic matter be removed as far as possible by a float-and-sink process, oil flotation, or acid extraction, before making the chemical analysis, instead of correcting the analyses for the errors introduced by high ash content. Such a procedure should reduce the ash content to an amount so low that the error could be disregarded for classification purposes. The committee desires to obtain suggestions on this question of ash correction or removal in connection with classification.

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5 Tideswell, F. V., and Wheeler, R. V., "Pure coal as a basis for classification": Tech. Pub. 104, Am. Inst. Min. and Met. Engrs., March, 1928.

6 Seyler, Clarence A., "The classification of coal:" Paper presented at New York meeting, Am. Inst. Min. and Met. Engrs., Feb., 1928.

Subcommittee III, on present and proposed systems of classification, is making an exhaustive study of the more important methods proposed for coal classification, with the object of correlating coals in each of the principal systems of classification.

Almost all scientific systems of classification are based on either proximate or ultimate analysis of the coal or on a combination of proximate analysis and calorific value. The principal systems under consideration by the subcommittee are the following:

1. On basis of proximate analysis, calorific value, and physical characteristics. U. S. Geological Survey[7] and Ashley systems.[8]

2. On basis of "unit coal" volatile matter calorific value. The Parr system.[9]

3. On basis of ultimate analysis. The Seyler[10] and Ralston[11] systems of plotting carbon, hydrogen and oxygen on a triaxial diagram.

4. On basis of physical and burning characteristics. The German or Continental European system.

Geological Survey Classification by Rank

The various ranks assigned to American coals in progressive order, beginning with the youngest stage in coal formation, are: Peat, lignite, subbituminous, bituminous, semibituminous, semianthracite, anthracite, and superanthracite. The bituminous rank is again subdivided into low-, medium-, and high-rank bituminous coal, and the semibituminous into low- and high-rank semibituminous coal. The criteria for classification are proximate analyses, calorific values, and certain physical characteristics of the coal; the proximate analysis is sufficient to differentiate the ranks from bituminous to anthracite, but physical characteristics are essential, in addition to the proximate analysis, for identifying subbituminous coals and lignite.

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7 Campbell, M. R., Prof. Paper 100 A, U. S. Geol. Survey, 1917-1922; Proc. Internat. Conf. on Bit. Coal., Carnegie Inst. of Tech., Pittsburgh, Pa., pp. 11-16.

8 Ashley, Geo. H., "A practical classification of coals": Proc. Coal Min. Inst. Am., 1923, pp. 29-36; "A use classification of coal": Trans. Am. Inst. Min. and Met. Engrs., Vol. 63, 1920, pp. 782-796.

9 Parr, S. W., "The classification of coal": Jour. of Ind. and Eng. Chem., Vol. 14, 1922, p. 919.

10 Seyler, Clarence A., Proc. South Wales Inst. Engrs., 1900, Vol. 21, p.483, et seq.; represented in Fuel in Science and Practice, 1924, Vol. 3, pp. 15-26, 41-49, 79-83.

11 Ralston, O. C., Graphic Studies of Ultimate Analyses of Coals: Tech. Paper 93, Bureau of Mines, 1915, 41 pp.

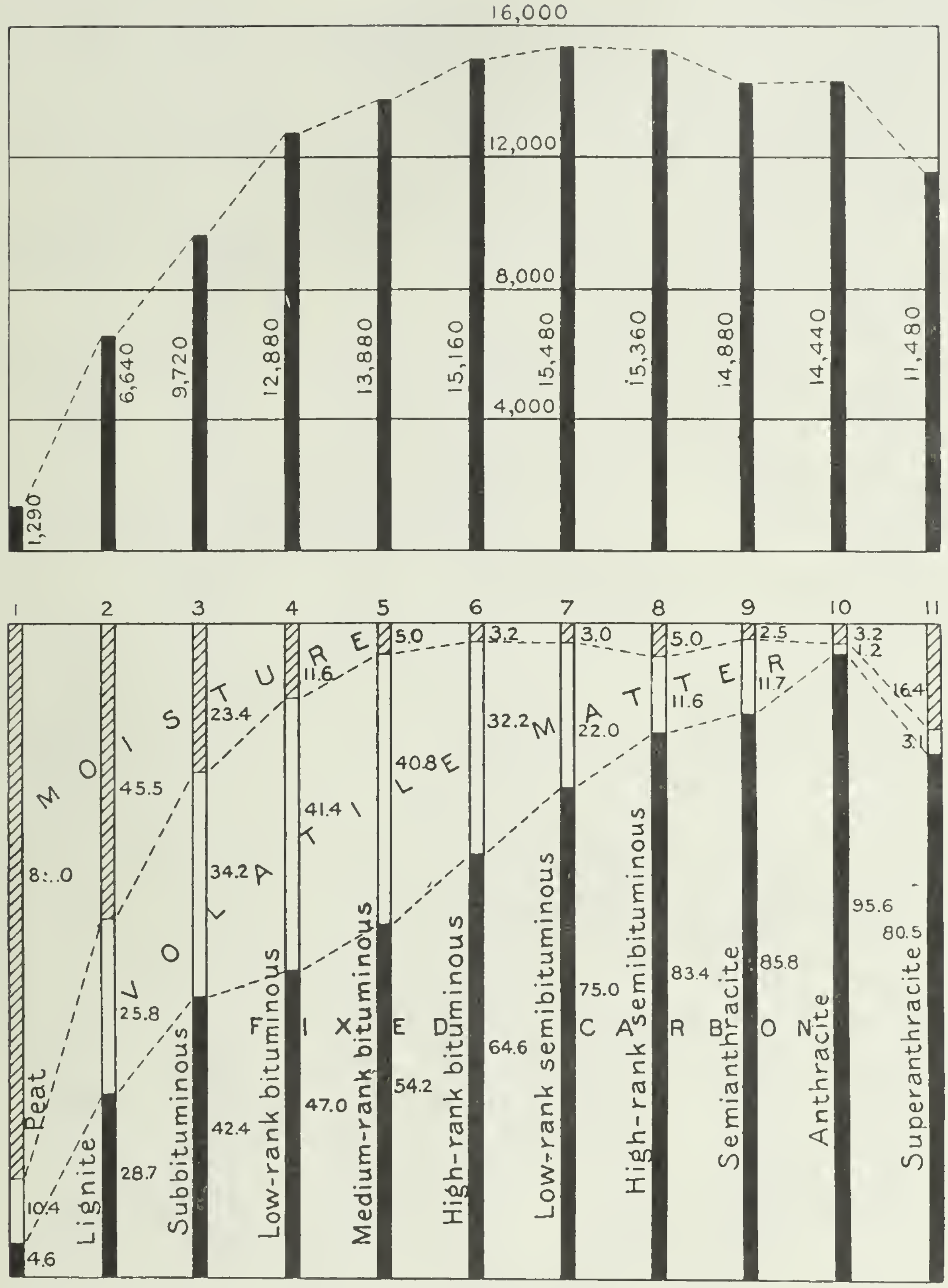


Figure 1.- Diagrams showing the average analysis of the various ranks of coal. The lower diagram shows the ash-free proximate analysis, and the upper diagram shows the moisture-and-ash free heating values expressed in B.t.u. (After M. R. Campbell.)

Figure 1 shows Campbell's graphic representation of the average ash-free proximate analysis, and the calorific value of the dry ash-free combustible matter of the various ranks. The upper diagram shows the progressive increase in the calorific value from peat to low-rank semibituminous coal. At this rank the calorific value attains a maximum and then decreases with further increase in rank due to the elimination of hydrogen that has taken place in the anthracitization of the coal by temperature and pressure in the earth's crust.

From these diagrams it is seen that the percentage of fixed carbon is the outstanding factor which shows the relative rank. Metamorphism of peat to coal consists of the gradual elimination of water and volatile matter. In the early stages water elimination predominates, and in the later stages volatile matter removal is the principal factor. Of course, not all of the volatile matter is combustible; part of it, especially in the early stages of metamorphism, is carbon dioxide and water. Geologists usually term this progressive metamorphism of coal to higher rank "carbonization," since it is indicated by an increase in fixed carbon and also of total carbon in the coal.

The term "fuel ratio," - that is, the ratio of fixed carbon to volatile matter expressed by the symbol FC/VM - is generally used by American geologists in setting the boundaries of the ranks of coal. This ratio applies very well to coals of medium-bituminous and higher ranks, but fails in the lower range due to the fact that the volatile-matter factor decreases with decrease in rank. A glance at the lower diagram of Figure 1 shows that the percentage of fixed carbon in the coal as mined but calculated free from ash may be preferable to the fuel ratio for indicating rank. It may be applied throughout the entire range of coals.

The upper diagram of Figure 1 also shows that the calorific value of the coal as occurring in the bed but calculated free from ash indicates rather definitely the proper position in the scale of rank for those coals which rank below semibituminous. This change is due to the progressive increase of moisture with decrease in rank, as shown in the lower diagram.

The system of classification based on the proximate analysis and calorific values, as shown in Figure 1, is supplemented by certain physical criteria, especially in differentiating between lignite, subbituminous, and low-rank bituminous coal. Lignite disintegrates or "slacks" readily on exposure to weather, and so does subbituminous coal, but not as rapidly or as completely as lignite. Low-rank bituminous coal slacks slowly and not completely. This slacking is directly proportionate to the bed moisture in the coal and can be predicted from the moisture content.

The Geological Survey system of classification by rank on the basis of proximate analysis and physical characteristics is practical and easily applied. In common with any system it has the disadvantage that the boundary lines between ranks are difficult to choose; there are no sharp boundaries - one rank merges into another. The boundaries must be arbitrary to a considerable degree. It is also true that not all coals with the same proximate characteristics are identical in properties. The volatile matter and fixed carbon do not occur in coal as such, but

are the results of heat treatment. To obtain comparable results these determinations must be made under definitely standardized conditions. For the last 15 years these determinations have been definitely standardized, and results by this standard method are strictly comparable; but unfortunately, before this period, standardization as to temperature of determination was not definite, and therefore all results in the literature are not comparable. Also the composition of the volatile matter varies with the composition of the coal. This factor introduces another variable. Hence, some variation must be expected in the qualities of coals with the same fixed carbon percentage.

Ashley's System of Use Classification

Ashley's system of use classification also is based on proximate analyses and physical factors, and is essentially similar to the Survey system, with slightly different groupings and analytical limits for the groups. The "use" part of the classification consists of assigning limits of ash and sulphur within the different ranks, thus indicating the grade of the coal. Ashley also gives representative ultimate analyses of the different classes of coal, and specifies certain physical characteristics, such as, "structure," "hardness," coking properties, flaming properties, etc. A new system of nomenclature is also provided.

Classification from Ultimate Analysis

From the standpoint of chemical composition, ultimate analysis appears superior to proximate analysis as a basis for classification. The ultimate analysis gives the chemical composition of the coal substance. The dominating chemical elements composing all plant substances are carbon, hydrogen, and oxygen. These also are the elements that compose coal; ash-forming material, sulphur, and nitrogen may be regarded as fortuitous, since their amount in coal has nothing to do with the rank or class of coal. Therefore, the relative proportions of carbon, hydrogen, and oxygen in the coal, calculated free from ash, sulphur, and nitrogen, should have an important relationship to the composition of the original organic deposit, the degree of metamorphism, and the properties of the coal itself.

This idea was first advanced by Regnault in 1837; it was later amplified and applied to European coals by Gruner[12] and by Seyler[5], and to American coals by Grout[13] and by Ralston[11]. Ralston's work is of special interest in the classification of American coals. In 1915 he published a Bureau of Mines technical paper on "Graphic Studies of Ultimate Analyses of Coals," in which he showed that the samples of coal represented in Bureau of Mines Bulletin 22 (where the first 10,000 analyses made by the Geological Survey and the Bureau of Mines are reported) and variously described according to the classification developed by former workers as anthracite, semianthracite, semibituminous, bituminous, subbituminous coal, and lignite, when plotted according to their ultimate analyses fall on the ternary diagram of carbon, hydrogen, and oxygen into certain definite fields that overlap to only a small extent.

12 Grüner, E. and Bousquet, G., Atlas Générale des Houillères: Deuxieme partie, texte, 1911, p. 16.

13 Grout, F. F., Economic Geology: Vol 2, 1907, pp. 225-241.

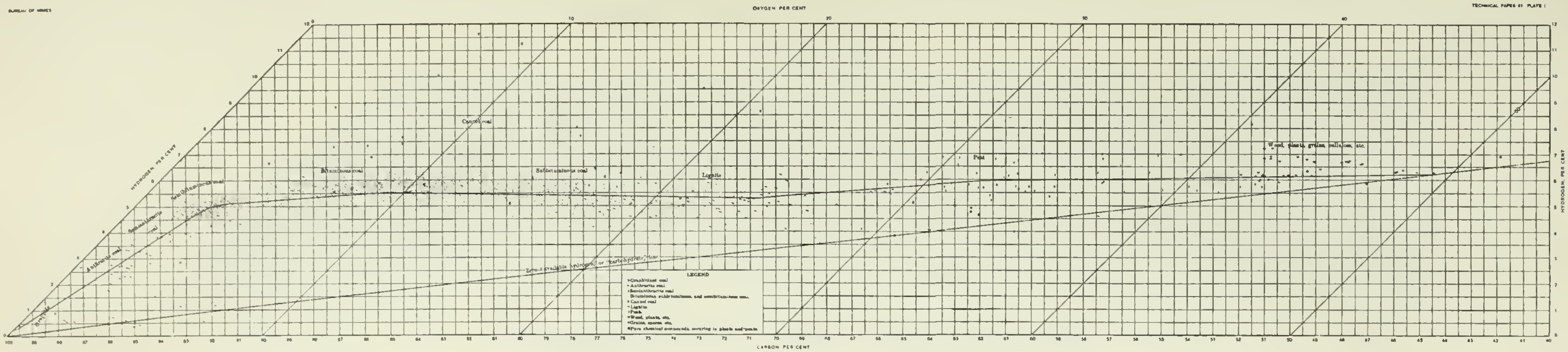
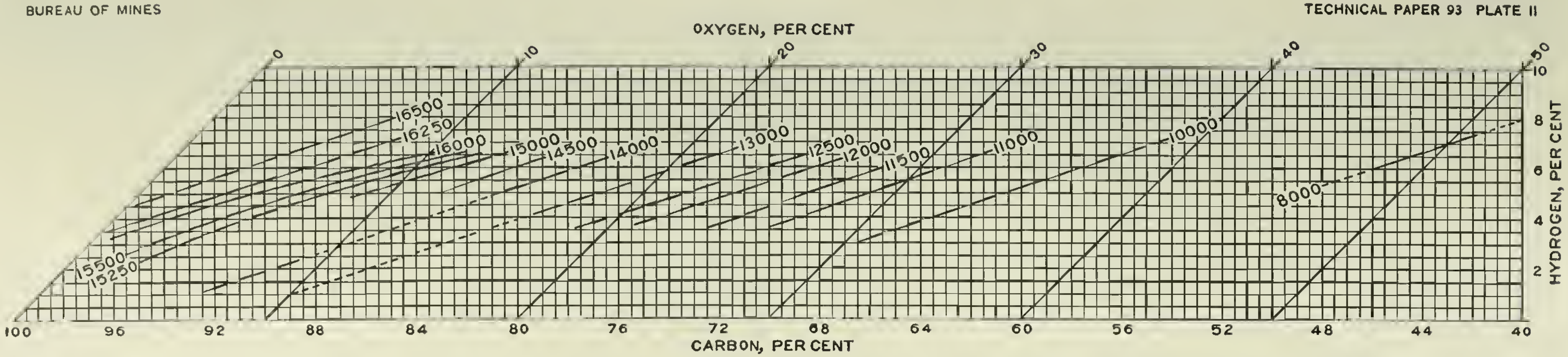
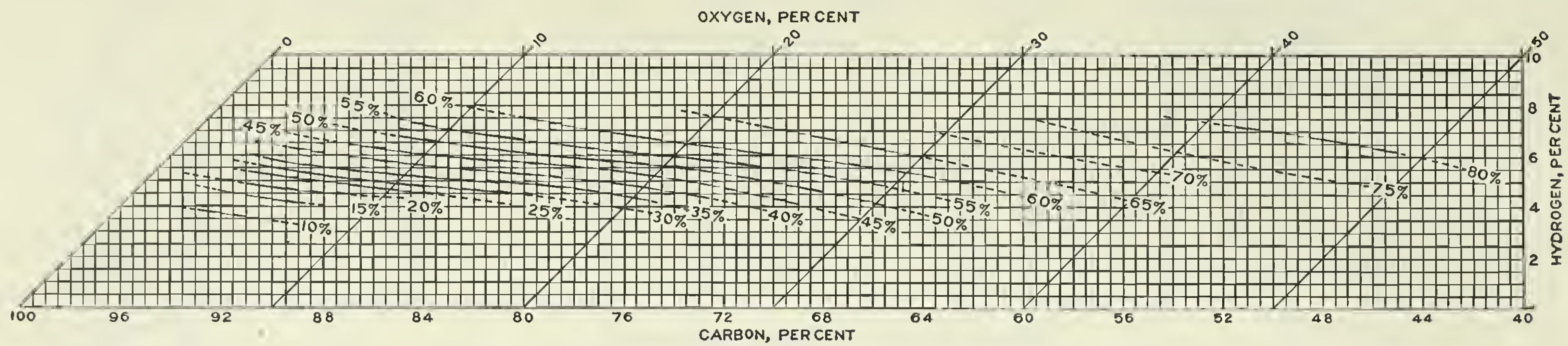


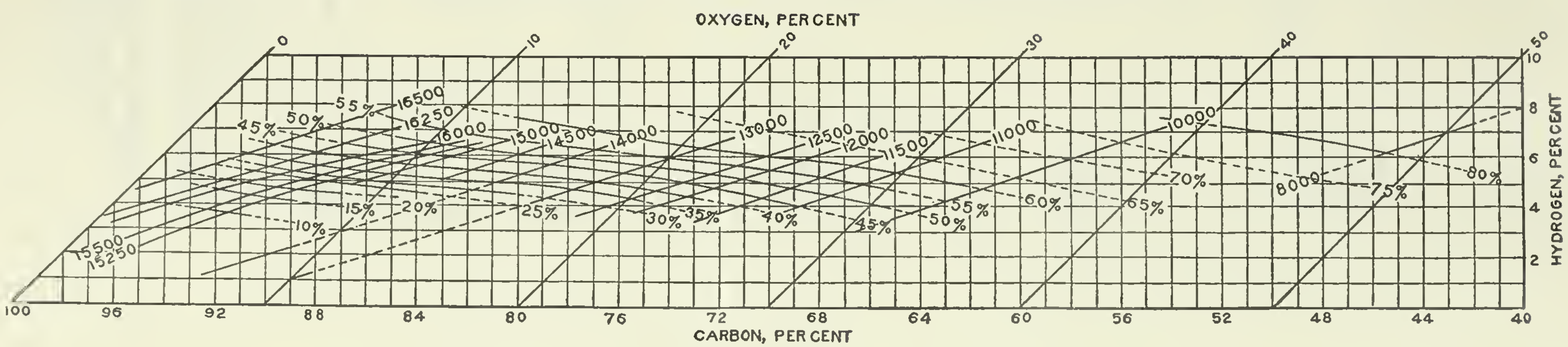
FIGURE 2.- GROUPING OF COALS ACCORDING TO HYDROGEN, CARBON, AND OXYGEN.
(AFTER RALSTON, TECHNICAL PAPER 93, U. S. BUREAU OF MINES.)



A. CURVES SHOWING RELATION OF THE CALORIFIC VALUE OF COALS TO THE ULTIMATE ANALYSIS. EACH CURVE IS DRAWN THROUGH POINTS REPRESENTING COALS OF EQUAL CALORIFIC VALUE.[1]



B. CURVES SHOWING RELATION OF VOLATILE-MATTER CONTENT OF COALS TO THE ULTIMATE ANALYSIS. EACH CURVE IS DRAWN THROUGH POINTS REPRESENTING COALS OF EQUAL VOLATILE-MATTER CONTENT.



C. DIAGRAM SHOWING RELATION OF ISOCALORIFIC AND ISOVOLATILE CURVES.

FIGURE 3.- RELATION OF THE CALORIFIC VALUE AND VOLATILE MATTER OF COALS TO THE ULTIMATE ANALYSIS. (FROM TECHNICAL PAPER 93, U. S. BUREAU OF MINES.)

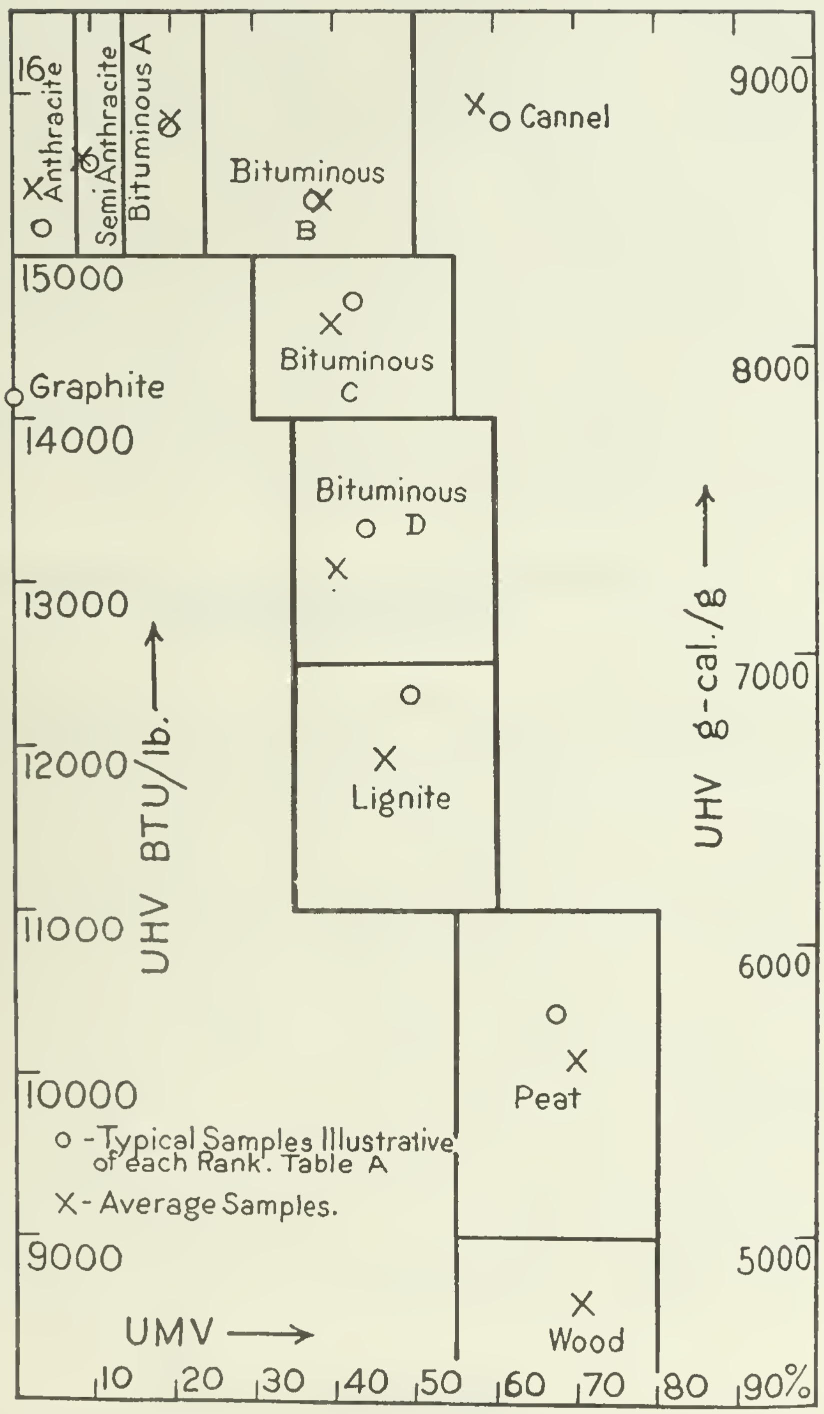


Figure 4.- Parr's system for the classification of coal. (From International Critical Tables.)

Figure 2 shows Ralston's diagram of trilinear coordinates. It will be observed that all of the analyses lie in a thin, narrow band extending across the lower part of the diagram, and that beginning with graphite on the extreme left at about 98 per cent carbon the various ranks of coal arrange themselves in the order of descending rank with decreasing carbon content and increasing oxygen content. Carbon and hydrogen are the principal variables in the upper ranks down to semibituminous coal. From semibituminous to lignite the hydrogen content is fairly constant and the oxygen and carbon vary. Carbon varies continuously throughout the range. Cannel coals, which are rich in spore matter, fall distinctly above the line of ordinary coals because of their higher hydrogen content. Nevertheless, they also fall into progressive ranks due to metamorphism. Their difference from the ordinary "humic" or "woody" coals is due to a difference in original plant material forming the coal. Ralston states that in plotting the analyses of coals from the bureau's records he used different marks to distinguish the different ranks of coal according to the accepted classification that was assigned to the coal by the field man sending in the sample. He found that each rank of coal usually fell into its proper group with little overlapping. This fact is remarkable because the system of classification used was that of the Geological Survey, based on proximate analysis. In view of this agreement it would appear logical that both systems have a scientific basis and that one can be translated into the other.

Relation Between Classification by Proximate Analysis and Ultimate Analysis

A very important deduction from Ralston's trilinear diagram is that a definite relation exists between the ultimate analysis of coal and its calorific value. Although this fact was previously known, since calorific values may be calculated to within 1 or 2 per cent by Dulong's formula, the diagram shows this relation more definitely and enables one to determine the ultimate analysis directly from the graph if one knows the volatile matter and the calorific value. Figure 3, the relation of the calorific value and volatile matter of coals to the ultimate analysis, shows intersecting "isocal" and "isovol" lines obtained by drawing the lines through points representing coals of equal calorific values and likewise through points representing coals of equal volatile matter. Corrections for sulphur were applied to the calorific values before plotting them. In this form of graphical representation either ultimate analyses or volatile matter plus calorific values can be applied to the identification of a given class of coal, or if the classification criteria are given in terms of percentage of carbon, hydrogen, and oxygen, the equivalent criteria for this class can be determined in terms of volatile matter and calorific value. This comparison is advantageous since proximate analyses and calorific values are more generally available than ultimate analyses.

Parr's Classification

Professor Parr[9] has utilized the relation between ultimate analysis and calorific value in his system of classification based on volatile matter and calorific value. Figure 4 shows Parr's system in which the calorific values in B.t.u. are plotted as ordinates and the percentages of volatile matter as abscissas.

Both values are given in terms of "unit" coal; that is, they are calculated free from moisture and ash and are corrected for sulphur and water of hydration of shaly matter. This system has the merit of simplicity as compared to the ultimate analysis system, but of course does not give as much differentiation of various kinds of coal. Nevertheless, its close relation to the ultimate analysis system and its ease of application justify its incorporation in any scientific method of classification.

Continental European Classification

The classification of European coals appears from the literature to be based largely on the behavior of the coal in a platinum crucible coking test and on the physical conditions of the solid residue from this coking test. Coals are classified as sand, sinter, or caking coals according to the degree of fusing or caking that has taken place in the solid residue of the volatile matter determination. Sand coals do not fuse or soften on heating, and they yield a powdery sandy residue. Sinter coals form a sintered residue in which particles are fritted together but have not fused to produce a porous structure. Caking coals fuse on heating and form a porous solid button.

Further classifications are made on the basis of relative length of flame of the burning coal and on the relative tar yields on distillation. These distinctions are covered by the terms "short flame" or "long flame" coals and "lean" or "fat" coals. It also seems customary in European practice to classify according to certain uses, as for example, coking coal, smithing coal, and gas coal are common commercial terms. There is, of course, no standard practice of European classification, but from a review of the literature, it seems that the various class terms should be placed in the following order of rank of coal:

Table III.- Continental-European Classes of Coal Arranged in Order of Rank

1. Peat.
2. Brown Coal.
3. Lignite.
4. Flame coal; long-flame sand coal; gas-rich sand coal.
5. Gas coal; long-flame fat coal; gas-flame coal.
6. Coking coal; smithing coal; fat coal.
7. Ess coal; semifat coal; short-flame fat coal.
8. Sinter coal; semilean coal.
9. Anthracite; lean sand coal; lean coal.

Grüner[14] and subsequent investigators[15] have proposed limits of ultimate

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14 Grüner; Ann. des mines, 1873, p. 169; Dingler Polytech. Jour., Jahrg. 213, p. 244.

15 Regnault; Ann. de chim. et phys., t. 66, p. 337.
Bauer; Beitrage zur chem. der Trockenen Distillation der Steinkohle: Rostock, 1908, p. 27.
Kukuk; Broockman's classification in "Unsere Kohlen," 2nd Ed., p. 21.
Strache, H.; and Lant, R.; Kohlenchemie, 1924.
Wirth, F., "Verlag of Geo. Stilke": Brennstoff-Chemie, 1922.
Schläpfer, P.; Private communication, 1924.

and proximate composition to the different classes, so that correlation can be made with American systems of classification.

Correlation of Systems

Mr. Rose's subcommittee is now engaged in correlating the various classification systems and in developing graphic methods for comparing them. It is evident that the ultimate analysis systems of Seyler and Ralston and the Parr system can be correlated in this manner; likewise the proximate analysis methods such as that of the U. S. Geological Survey and the one proposed by Ashley can be compared to the others, perhaps less directly, but nevertheless with sufficient accuracy to permit the setting up of limits for those groups of coals which have similar characteristics, so that each coal may be placed in any system. From these comparisons the committee hopes to work out eventually the best combination of analytical and other criteria for a scientific classification of coal.

WORK OF THE TECHNICAL COMMITTEE ON USE CLASSIFICATION

The technical committee on the use classification of coal is charged with making a study of the possibilities in the development of such a classification, if desirable, possible, and equitable, based principally on the uses of coal and commercial practice, but also correlated with scientific classification in so far as is thought desirable or possible. One of the objectives of this committee is to determine how far the scientific classification may be of use in commercial practice. Another objective is to secure data on the different uses for coal and the requirements for these uses. To attain this end, subcommittees were appointed to obtain data on the following uses and types of coal:

1. Gas making: water gas, coal gas, and producer gas.
2. Coke making.
3. Coal used in the brick and tile industries.
4. Coal used in the cement industry.
5. Coal used in the metallurgical industry.
6. Smithing coal.
7. Railroad coal.
8. Stationary steam generation.
9. Domestic bituminous coal.
10. Domestic anthracite coal.

Considerable information has been assembled by the subcommittee on gas coals, coal for water-gas generators, and coal for producer gas. Specifications and desirable characteristics for these classes of coal are outlined in the first report of this subcommittee.

The subcommittee on coals for stationary steam generation also has submitted a comprehensive preliminary report on the desirable characteristics of coals for hand firing, for different types of stokers used in steam power plants, and for pulverized fuel combustion. Obviously, no hard and fast rules can be laid down for such coals, since costs and available supply are important factors.

The task before the use classification committee is a large one, and several years will be required to assemble all the needed information.

WORK OF THE TECHNICAL COMMITTEE ON MARKETING PRACTICE

The technical committee on marketing practice is to collect and correlate information on marketing practice with reference to classification, and for the benefit of the other two technical committees. In order to collect data on marketing practice and classifications now in use, subcommittees were appointed to cover the various marketing areas of the country. These areas are as follows:

1. Anthracite (all markets).
2. New England.
3. Coastwise (tidewater), export and bunkers, and Atlantic States inland.
4. North.
5. South.
6. Southwestern.
7. Rocky Mountains.
8. Pacific Coast.
9. Central (east of Mississippi River).
10. Southern inland.
11. Lakes and Northwest.
12. Canada, Eastern, and Central.
13. Canada, Western.

Of these subcommittees, three have already completed comprehensive reports; namely, those on anthracite, the Pacific coast, and the Rocky Mountains region. The data being obtained are proving to be particularly valuable to the use classification committee.

SUMMARY AND CONCLUSIONS

In summarizing the program of the sectional committee on the classification of coal the following important considerations are being kept in mind:

1. Coal should be classified primarily on the basis of its intrinsic chemical and physical properties. These properties involve the origin, composition, and constitution of the coal.

2. Use classification should be secondary to scientific classification and should be correlated with the scientific classification as far as possible.

3. Scientific classification depends on two primary factors: First, the composition and type of the original coal forming vegetation, and second, the degree of metamorphism or coalification of the vegetable residue.

4. The first factor is described broadly in the type of the coal, as xyloid canneloid, or boghead; the second factor in the progressive rank of the coal as expressed in the series from lignite to anthracite.

5. The criteria to be considered for classifying under these two general factors are proximate and ultimate analyses, calorific values, microscopic examination, extraction with solvents, reaction with reagents, and destructive distillation.

In conclusion, it may be said that the work of the various committees is now well under way. The project is of great magnitude and of the highest importance. Uniform classification should be a great aid to a better understanding between seller and buyer, and should result in directing each class of coal into the use for which it is most valuable. This great international conference is evidence that many new uses for coal are impending. These uses must be taken into consideration in revising our present classifications. The committee on use classification wishes to enlist interest and cooperation in the project. Help is needed from research, educational, and industrial organizations in collecting data on coal and in solving the many problems that arise in correlating analytical characteristics with constitution and use of the coal. The committee is indeed fortunate in having the valuable cooperation of the Mines Department and National Research Council of Canada. This arrangement will insure uniformity in classifying the coals of North America.

The organization of separate committees on scientific and use classifications promises to do away with much unprofitable argument in the progress of the work. It provides clean-cut objectives for each group, and permits the scientists to develop their ideas unhampered by commercial considerations. On the other hand, the engineers and commercial men concerned with producing, distributing, and using coal are able as members of the use classification committee to work out their ideas with the advice of the scientific men who compose a minority on the committee. The scientific committee consists chiefly of chemists, geologists, and paleobotanists, but there is also included a minority of practical fuel engineers to keep the scientists from wandering into the field of impracticability.

After each of the two technical committees has reached a satisfactory conclusion in the work of classification, and has submitted a report, the entire committee will probably take steps to harmonize use classification and scientific classification as far as is possible. It is not unlikely that the final result will be a simple system of classification, both scientific and useful.

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Circular No. 6096.
January, 1929.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

STATE REGULATIONS GOVERNING EXPLOSION PROOF TYPE ELECTRIC MOTORS IN COAL MINES[1]

By L. C. Ilsley [2]

So many subjects are covered in State mine-safety regulations that any attempt to compare different State laws in their entirety would be futile. On the other hand, if one selects a single phase or branch of safety work, such a comparison may prove profitable. The subject selected for study in this paper is limited to legislation or regulations dealing specifically with safeguarding (electric) motored equipment used in gassy mines.

When one reads glowing accounts of the safety activities being carried on here and there it is easy to believe that everything which is right and proper is being done to safeguard the mine workers; but, when one takes time to look into the weakness of many State regulations, it is evident that there is still room for improvement.

Undoubtedly it would have been much better for the safety of mines if electrical equipment had been introduced into mines 50 years earlier. If electricity had been in general use when the first mine regulations were prepared, those formulating the rules would have covered this hazard along with other hazards, but as electricity came in at a later period, safe mine legislation regarding it has been woefully neglected. Today the United States in general is far behind most other coal-producing nations in the provision of adequate safety rules or laws for the installation and maintenance of electrical equipment and wiring.

Returning to the subject of our study, approximately 30 of the 48 States mine coal. More than 20 of these States produce coal in large quantities. However, of the 30 States only four,[3] Pennsylvania, Utah, Washington, and West Virginia, have laws which specially call for the use of explosion-proof types

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1 - The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"

2 - Electrical engineer, U. S. Bureau of Mines.

3 - The Maryland mining law is so worded that it may be amended to require explosion-proof motors if the Maryland Bureau of Mines deems their use advisable.

of equipment in gassy mines. It would be more exact to say that only 3 1/2 States have such legislation or rules, because the large coal-producing State of Pennsylvania has no such legislation applying to the anthracite field.

For comparison and for the possible use of any State that may have in mind a modification of the present laws, specific regulations dealing with explosion-proof equipment have been abstracted from the regulations of the four States, as follows:

BITUMINOUS MINING LAWS OF PENNSYLVANIA
ARTICLE XI
Amended to 1927

Definitions

Explosion or Flame Proof.--Explosion or flame proof casings or enclosures are those which, when completely filled with a mixture of methane and air, and the same exploded, are capable of either entirely confining the products of such explosions within the casing or of so discharging them from the casing that they can not ignite a mixture of methane and air, combined in proportions most sensitive to ignition and entirely surrounding the points of discharge, and in most intimate proximity therewith.

Section Three - Trailing Cables

59. In gaseous portions of mines, a fixed terminal box shall be provided at the points where trailing cables are attached to the power supply. This terminal box shall be flame-proof and shall contain a switch and fuse on each pole of the circuit. The switch shall be so arranged that it can only be operated from without the box, when the latter is completely closed, and the switch shall also be so constructed that the trailing cables can not be attached or removed when the switch is closed.

Section Five - Motors in Gaseous Mines

67. In any gaseous portion of a mine, all motors, unless placed in such rooms as are separately ventilated with intake air, shall have all their current carrying parts, also their starters, terminals, and connections, completely enclosed in explosion-proof enclosures made of non-inflammable material. These enclosures shall not be opened except by an authorized person, and then only when the power is switched off. The power shall not be switched on while the enclosures are open.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Section Five - Electric Coal-Cutting Equipment

71. No man shall be placed in charge of a coal-cutting machine in any gaseous portion of a mine who is not a competent person, capable of determining the safety of the roof and sides of the working place and of detecting the presence of explosive gas.

72. In any gaseous portion of a mine, a coal-cutting machine shall not be brought within the last break-through next the working face, until the machine man shall have made an inspection for gas in the place where the machine is to work, unless such examination is then made by some other competent person authorized or appointed for that purpose by the mine foreman. If any explosive gas be found in the place, the machine shall not be taken in.

73. No coal-cutting machine shall be continued in operation in a gaseous portion of a mine for a longer period than half an hour without an examination as above described being made for gas, and if gas is found the current shall at once be switched off the machine, and the trailing cable shall forthwith be disconnected from the power supply.

74. The person finding gas shall at once report the fact to the fire boss or mine foreman, and the machine shall not again be started in such place until the fire boss, or a person duly authorized by the mine foreman, has examined it and pronounced it safe.

75. The person in charge of a coal-cutter or drilling machine shall not leave the machine while it is working, and shall, before leaving the working place, see that the current is cut off from the trailing cables.

76. In any gaseous portion of a mine, if any electric sparking or arc be produced outside of a coal-cutter or other portable motor, or by the cables or rails the machine shall be stopped, and not be worked again until the defect is repaired, and the occurrence shall be reported to an official of the mine.

Section Six - Electric Locomotives Trolley System

77. Electric haulage by locomotives operated from a trolley wire is not permissible in any gaseous portions of mines, except upon the intake air, fresh from the outside.

Storage Battery System

79. Storage battery locomotives may be used in gaseous mines, only when all electrical parts that it is practicable to enclose are enclosed in flame and explosion proof casings.

In addition to the electric regulations already given under Article XI of the Pennsylvania Bituminous Code, there is a brief reference under Article IX, Section w, paragraph 5, to the use of fans in mines as follows:

> Booster and/ or blower fans shall not be used in gaseous mines for the purpose of ventilating workings having no connection with the air circuit, unless equipped with government approved, flame-proof, electric motor: Provided, however, that the location of such fans shall have the approval of the inspector of the district.

UTAH GENERAL COAL MINE SAFETY ORDERS

(Amended to July 1, 1924.)

Section 37 - Haulage Locomotives

(b) In gaseous mines, or any part thereof, where permissible lamps are required to be used, electric trolley locomotives must not be used on any haulage way, except it be an intake airway. This should not prevent coal from being pulled from the back entry, either in advancing or retreating. Trolley wires must be kept back of the last break-through and at least fifty (50) feet back of the first room where pillars are being drawn.

(c) Electric storage battery locomotives when used in such gaseous mines shall only be used the same as electric trolley locomotives unless they are of explosion-proof make.

Section 46 - Coal Mining Machines

(g) In gaseous workings where permissible lamps are required only approved explosion-proof mining machines will be allowed, unless permission to the contrary is given in writing by the Industrial Commission.

WASHINGTON COAL-MINING LAWS
(Amended to 1927)

Section 154 - Motors in Gaseous Mines

In any gaseous portions of a mine, all motors, unless placed in such rooms as are separately ventilated with intake air, shall have all their current-carrying parts, also their starter, terminals and connections, completely closed in explosion-proof enclosures made of noninflammable materials. These enclosures shall not be opened except by an authorized person, and then only when the motor is switched off. The power shall not be switched on while the enclosures are open.

No coal-cutting machine shall be continued in operation in a gaseous portion of a mine for a longer period than half an hour without an examination being made for gas, and if the gas is found the current shall at once be switched off the machine, and the trailing cable shall be forthwith disconnected from the power supply.

The person finding gas shall at once report the fact to the fire boss or mine foreman, and the machine shall not again be started in such place until the fire boss, or a person duly authorized by the mine foreman has examined it and pronounced it safe.

The person in charge of a coal cutter or drilling machine shall not leave the machine while it is working, and shall, before leaving the working place see that the current is cut off from the trailing cables.

In any gaseous portion of a mine if any electric sparking or arc be produced outside of a coal-cutting or other portable motor, or by the cable or rails, the machine shall be stopped and not worked again until the defect is repaired, and the occurrence shall be reported to an official of the mine.

WEST VIRGINIA STATE MINING LAW

(Effective July 21, 1925)

Electric Coal-Cutting Machines

Sec. 37. All electric coal-cutting machines used in gaseous portions of the mine shall be flame-proof, and be approved by the department of mines. No man shall be placed in charge of a coal-cutting machine in any gaseous portion of a mine who is not a competent person, capable of determining the safety of the roof and the sides of the working places and detecting the presence of explosive gas. Machine runners shall be compelled to undergo an examination to determine their fitness to detect explosive gas before they are permitted to have charge of machines in mines liberating gas, unless they be accompanied by a certified fire boss, or a man having passed such an examination. Said examination to be given by the mine foreman, blank forms for same to be furnished by the department of mines, a copy to be retained on file at the mine office and the original sent to the department of mines, fully made out and signed by the machine runner and mine foreman.

Sec. 38. In any gaseous portion of a mine, a coal-cutting machine shall not be brought within the last break-through next the working face, until the machine man shall have made an inspection for gas in the place where the machine is to work, unless such

examination is then made by some other competent person authorized or appointed for that purpose by the mine foreman. If any explosive gas is found in the place, the machine shall not be taken in until the gas is removed.

Sec. 39. In working places where gas is likely to be encountered, a safety-lamp, or other suitable apparatus for the detection of fire damp, shall be provided for use with each machine when working, and should any indication of fire damp appear on the flame of the safety lamp, or other apparatus used for the detection of fire damp, the person in charge shall immediately stop the machine, cut off the current at the nearest switch, and report the matter to the mine foreman, or fire boss, and the machine shall not again be started in such place until the mine foreman, fire boss, or a person duly authorized by either has examined it and pronounced it safe. All coal-cutting machines shall be provided with a box specially designed for carrying safety lamps for the protection of such lamps.

Sec. 40. No coal-cutting machine shall be continued in operation in a gaseous portion of a mine for a longer period than half an hour without an examination as above described being made for gas, and, if gas is found, the current shall at once be switched off the machine, and the trailing cable forthwith be disconnected from the power supply.

ANALYSIS OF THE LAWS AND REGULATIONS QUOTED

The working of the laws and regulations just quoted undoubtedly has a considerable bearing on electrical safety in the four States. The fact that there is a law or regulation bearing on the subject of electrical equipment in gassy sections of the mine is of considerable aid to the State Inspector in carrying out his safety program. Again, the presence of the safety requirements in the regulations has brought about the introduction of a large amount of specially designed equipment for use in atmospheres that may become dangerous.

There are some real weaknesses in the electrical-equipment regulations as they now stand, however, owing to their lack of definiteness with reference to construction, inspection, and maintenance.

In regard to construction, the term explosion-proof or flame-proof is used, but with the exception of Pennsylvania, there is no definition of what this terms means. How is an inspector to judge whether or not a motor or switch is explosion-proof? Will he look at the outside of the equipment? Will he accept the manufacturer's statement concerning its safety? Will he dismantle the equipment and go over its construction in detail? If so, by what standard will he judge its safety? Will he test it out in explosive mixtures? If so, what will be the test conditions and where shall the tests be made? As far as the regulations are concerned, the inspector is in a hopeless quandary.

Assuming that in some way the inspector has obtained properly constructed equipment, the law does not help him very much in regard either to routine or occasional inspection of the parts to see that they are in a safe condition. Neither do the regulations require the State Inspector to give electrical equipment his special attention.

Regulations covering maintenance of electrical equipment are lacking. Much of the explosion-proof equipment can easily become unsafe if it is not properly maintained. Several mine disasters have unquestionably been caused by supposedly explosion-proof equipment that had been totally neglected as to maintenance. There are undoubtedly a large number of machines which the State Inspectors may judge to be safe that, owing to improper maintenance, are no safer than open-type equipment.

The foregoing comments refer to those States that have some regulations concerning the use of electrical equipment in mines. What shall be said for those States that have none? Is mine gas less explosive in Illinois than in Alabama? Is an electric arc any different in Indiana than in West Virginia? Should not the same protection be offered to the men working at the face in Oklahoma and Colorado as in Utah and Washington? There is truly much remaining to be done in the way of legislation to bring about greater safety in the use of electricity in mines.

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Circular No. 6098
January, 1929.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

ELECTRICAL SAFETY INSPECTION: SUGGESTIONS FOR MINE-SAFETY ENGINEERS[1]

By L. C. Ilsley[2]

This paper is a revision of Reports of Investigations, Serial 2541, which was published in November, 1923, for the benefit of State mining inspectors, safety engineers of mining companies, and others interested in electrical safety inspection in mines. It presents the important points that should be watched by inspectors and briefly reviews the work of the Bureau of Mines in testing of electrical apparatus and equipment to determine their permissibility for use in gassy coal mines.

Important Points in Inspecting Mine Electrical Installations or Equipment

The following questions and the precautionary measures mentioned are intended as suggestions to a safety inspector who may not have been specially trained in looking for defects in electrical installations or in the maintenance of electrical equipment:

1. Is there some one in charge of electrical equipment who is fitted for the position by ability, training, and experience?

The electrician should not be assigned to other duties but should spend his entire time looking to the safety of the electrical installations.

2. Is a systematic recorded inspection of electrical equipment made at least once each month?

Some organizations employ outside electrical experts to make inspections of electrical equipment and report thereon.

3. Is a plan map of the mine kept, showing all permanently installed electrical machinery and apparatus, including cables, conductors, lights, etc.?

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1 - The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"
2 - Electrical engineer, U. S. Bureau of Mines.

4. Are instructions for resuscitation from electric shock posted in each surface and underground electrical station, also at the entrance of the mine and in the first-aid station, and are the employees who work on electrical equipment trained to apply these instructions in case of accident?

5. Are all electrical workers, including operators of electric machines, required to practice artificial respiration at definite intervals?

6. Are prohibitory notices posted wherever there is electrical apparatus that should not be operated by unauthorized persons, and are caution notices posted where such warning will be most effective in reducing the likelihood of electrical contact?

7. Are persons allowed to work on or with electrical equipment of any kind before they have been properly instructed in their duties?

8. Are the metallic frames, casings and coverings of stationary apparatus grounded?

Grounding of metallic apparatus is essential if electric shock accidents are to be minimized. It is not easy to be sure of a good ground in a mine. A well-bonded track return or a pumping system having a continuous metallic connection to the surface should afford a good grounding point. It may be necessary to carry a ground return to the surface, as is the British custom. By putting a copper plate down about 4 feet in the earth and imbedding it in charcoal an excellent surface ground is assured. The connection to the casing and to grounding point should be carefully made. The wire used for the ground should be capable of carrying full-load current for the system being grounded.

9. Are the metallic sheaths or coverings of cables or wires grounded?

This should be done as a preventive against shock. The same suggestions hold as for grounding motor frames, etc.

10. Are the metallic sheaths and armors of electric cables electrically continuous throughout their length so that there can be no voltage difference between different sections?

Electric cables often carry high voltages, and if a fault occurs in the cable, the sheath becomes charged with a high potential. A continuous grounding of the sheath or armor throughout the length of the cable reduces the shock hazard that would otherwise exist.

11. Are power circuits properly installed?

Armor-covered circuits need not be supported on insulators but should be secured by wooden clamps or other suitable means sufficient in number to insure that the cable is kept in alignment and away from mechanical injury. The greatest hazard to such cables will undoubtedly be from falls of roof; props should

be placed where there is danger of this additional hazard. Other power cables should be supported on insulators, preferably of porcelain, placed not less than 30 feet apart and closer together where the cable is run around curves. The cable should be so installed that it does not rest against rock, coal, timber, or other conducting material. Hanging of insulated cables on spikes or allowing them to lie on mine timber is dangerous practice. Boreholes should be cased. Power wires of different voltage and service in the same borehole should be in separate conduits with the conduits grounded to casing. As shaft wiring is a fire hazard it should be installed in a conduit or metallic armour.

12. Are lighting circuits properly installed?

Lighting circuits usually have the same voltage as the power circuits and should be installed with the same care, although owing to the small-size wires used, smaller insulators and a lighter line construction can be used.

13. Are telephone circuits properly installed?

Telephone circuits are usually twisted pairs; they should be kept separate from power and lighting circuits and be supported by sufficient insulators to keep the circuit free from rock and timber.

14. Are signal circuits properly installed?

The proper operation of signal circuits is usually important. Signal circuits should, as far as feasible, be separate from other circuits; they should be carefully installed in conduit or on suitable insulators and kept as free as possible from mechanical injury.

15. Are permanent shot-firing circuits properly installed?

In some mines permanent shot-firing lines are used. These should be protected from lightning if they enter the mine from the surface. They should be installed separately and apart from all other circuits and should be amply safeguarded by a system of locked switches.

16. Are rubber-covered temporary shot-firing lines used?

Cotton-covered wires are neither safe nor suitable for shot-firing service. The insulation is so poor that there is a great liability of picking up stray electric current from other electric circuits and of consequent premature shots.

17. Are trolley circuits properly installed?

A trolley circuit to give good service should, as far as feasible, be strung at a uniform height and have enough insulators to give the line the same contour as the track. Insulator supports should be such as to keep the circuit from touching the roof or sides of the rock, coal, or timbers. The wire should

be taut and the hangers so spaced that the trolley wheel will not touch the roof between hangers. In new installations and in the changing of old systems, serious consideration should be given to keeping the voltage to 250 volts. Many States legislate against 500 volts, and there is much adverse sentiment among safety men against this higher voltage in mining work, more especially on trolley systems which are blamed for a large percentage of the accidents from electric shock.

18. Are trolley circuits properly guarded?

Trolley citcuits should be guarded at all points where men must cross under them and along all roadways used as travel ways when the trolley is alive.

19. Are unarmored power and lighting circuits guarded?

The insulation, weatherproof or rubber-covered, should not be depended upon to prevent shock, and unarmored circuits should be guarded the same as bare wire at all points where there is a likelihood of accidental contact. When power and lighting circuits pass over points where men must work they can be effectively guarded by running in a grounded conduit or by boxing.

20. Are "section switches" properly installed and maintained?

Switches are used to sectionalize trolley and feeder circuits. Such switches should be placed in a dry place where they can be operated without hazard from passing trips. Section switches should be mounted with the hinge down so that an open switch can not accidentally close by gravity. Switches should not be allowed to get out of repair or be so poorly grounded that they can not be operated by hand. In certain places the adoption of the safety-type enclosed switch instead of the open-type switch would add materially to the safety. On account of space and moisture conditions it is not deemed advisable to recommend the general use of enclosed-type switches.

21. Are oil switches properly installed and maintained?

Oil switches should, as far as feasible, be installed at such points as to keep moisture and dust out of the switch. The oil of these switches should be kept at the required level and should be periodically changed. Moisture sometimes collects and settles at the bottom of the oil switch. If this water is not drained off but allowed to accumulate, the switch may short-circuit.

22. Are all rheostats and other means of regulating the speed of the machines kept in good repair?

The safe operation of any machine depends largely upon the condition of the starting device. Such devices should be carefully maintained in good condition in order that the machine may be started up normally without undue sparking or strain on the insulation.

23. Are all fuses and circuit-breakers kept in good repair?

Fuses and circuit-breakers are the safety valves of an electric circuit. They blow or open when the current in the circuit reaches the predetermined safe value. If this warning is not heeded, then the wiring or the apparatus itself is likely to suffer the consequences. Any one using oversize fuse wire, solid wire instead of a fuse, or any other means of defeating the fuse deserves to be disciplined.

24. Inspection of electric locomotives.

All electric locomotives should be provided with fuses or other adequate means of protecting the wiring. The controller should be provided with a suitable blow-out coil in order that the arcing between fingers and segments shall not be excessive. Gongs should be provided and maintained. Locomotives should be provided with adequate bumper guards to prevent cars from climbing the locomotive and crushing the motorman. Headlights should be kept in good repair. Maintenance of the brakes and the supply of clean, dry sand affect the safe operation of the locomotive. Frequent inspection of the wiring, also of the motor, controller, and rheostat tend toward good operation and may reduce accidents. No material other than that necessary for its operation should be allowed on a locomotive. No one but the motorman and his helper should be allowed to ride on a locomotive.

In inspecting a permissible locomotive the inspector should carefully note the caution statement on the approval plate and take time to ascertain whether the various suggestions are being carefully carried out and whether the locomotive is kept in a permissible condition in every respect.

25. Inspection of electric hoists (surface).

Electric hoists installed on the surface and used to hoist men should be carefully inspected to ascertain whether they have been equipped with safety devices.

All electrically operated shaft hoists should be provided with a device approved for the prevention of overwinding. Where the hoist is used for handling men, additional provision should be made to prevent overwinding at the man landing. Where a separate overwind protection for men is used, a visual signal should be provided to indicate at all man landings that the overwind device is set for hoisting men. It should not be possible to operate the signal lights without setting the man landing overwind.

Shaft hoists should have a brake that will keep the hoisting drum under the control of the operator. This brake should be provided with an automatic trip or release to apply the brake if the power supply fails or in case of overwinding or overspeeding; this brake should also have sufficient capacity to hold the maximum unbalanced load. Any contingency which will cause an emergency

application of the brake should at the same time remove power from the motor. The hoist should not be maneuvered unless all equipment, including protective devices, are in normal operating condition.

Hoists for handling men should be so arranged that when the legal rate of speed is exceeded in hoisting and lowering men, the hoist will automatically be brought to a stop. If hoists are designed to operate in balance the driving motor should be of sufficient size to hoist full loads of men in a maximum unbalanced condition in case of emergency.

All electrical safety devices should be tested at the beginning of each shift, and a record of such tests should be made and signed by an authorized person and kept on file at the mine.

26. Inspection of electric hoist (underground).

Stationary electric hoists should be installed on rigid fireproof foundations and housed in fireprood rooms. The power and light wiring within the hoist room should either be installed in a conduit or supported on insulators so placed that it is neither a hazard from overhead or under foot. Slack wiring, while not always a hazard, gives the appearance of careless workmanship. Hoists should be provided with ample brakes, and these should be maintained in order that the engineer shall at all times have complete control of his trip. Signals used in connection with the hoist should be installed properly and always maintained in first-class order. Persons having no duties to perform should not be allowed in the hoist room because they may distract the engineman from his duties.

The wiring of portable hoists should receive special attention as the service is severe. If trailing cables are used with hoists they should be specially designed for that service and kept in good repair.

27. Inspection of portable electric drills and drilling machines.

Portable electric drills are sometimes held in the hands during operation. For this reason the frames of drills should be adequately grounded, so that if a frame becomes charged with electricity the operator will not receive a shock. The trailing cable used on drills should be especially designed for this service and maintained in good condition.

The same recommendations are made for grounding and for the maintenance of trailing cables on drilling machines.

28. Inspection of electrically operated coal-cutting equipments.

As electrically operated coal-cutting equipments are the attributed source of a number of fatal accidents each year, their inspection is important. These accidents may be divided into three general classes, as follows: (1) Accidents caused by getting caught in the machinery; (2) accidents due to touching

a charged machine; (3) accidents due to handling defective trailing cables. Accidents of the first class can be lessened by using a guard over the cutter chain, by having no loose wearing apparel to catch on moving parts, and by strictly prohibiting crawling or stepping over machines while they are in operation. Accidents of the second class can be minimized by a daily inspection of the machine for electrical faults, especially testing for grounds. Worn or defective electrical parts should be replaced. The machine should be kept free from accumulations of grease and dirt. Accidents of the third class can be greatly lessened by using a good grade of rubber-sheathed cable and by not using a spliced cable. Cables whose splices have been carefully made electrically and then vulcanized can be used with a fair degree of safety. A careful inspection should reveal the degree of attention given to each of the foregoing.

Only permissible-type equipments should be installed in gassy mines. Permissible equipments carry their own identification card. If an inspector is in doubt he should look for the approval plate; in fact, he should invariably find and carefully read the approval plate on every permissible outfit. He will find valuable hints in the caution statement relative to the proper inspection and maintenance of the machine. The inspector should make sure that all precautions are being observed and that the machine is being maintained in a safe condition fit for service in a gassy mine. Trailing cables, if not properly maintained, offer a special hazard.

29. Inspection of loading machines and conveyor systems.

A number of makes of permissible-type loading machines and conveyors are in daily use at mines. The inspector should be guided to a large extent by hints given on the "caution statement" of the approval plate. If he finds all these precautions being strictly followed, it portends well for the safety of the equipment in general. In the case of unapproved machines the inspector should strive toward the same wiring standards as practiced on permissible equipment.

30. Inspection of miscellaneous electric motors.

In and around mines are electric motors used for miscellaneous purposes. The general condition of all such installations should be ascertained. Motors on drag lines, conveyors, and other machinery should be provided at or near the machinery with a stopping device, so that in case of accident the machinery can be stopped immediately. Wherever feasible, the starting device for a motor should be in sight. All miscellaneous motors should be regularly inspected for wear of commutator and bearings, also the condition of fuses, switches, and control apparatus should be noted. In many instances it is essential that the motor be periodically cleaned of dust accumulation.

31. Suggested practice for control of alternating current motors.

On three-phase delta or Y (star)-connected circuits, each wire should be provided with a fuse or automatic circuit-breaker. When circuit-breakers

are employed, two overload trip-coils should be used for ungrounded neutral systems, and three overload trip-coils for grounded neutral systems. In either case the automatic circuit-breakers should be so arranged that the opening of one will open the others. Switches for isolating the fuses or circuit-breakers from live source should be provided. If air-break circuit-breakers which trip free from the handle are used, the switch may be omitted.

These devices should be installed in a convenient position in sight of the motor or in sight of the equipment operated by the motor. The controlling appliances of stationary motors, except the controllers of hoists and similar equipment, should be mounted upon a switchboard. Resistances may be mounted upon a separate metallic framework.

32. Suggested practice for control of direct-current motors.

Every stationary motor and every portable motor used underground (except mining machines and drills), together with its starting device, should be protected as follows:

On two-wire ungrounded circuits, each wire should be protected by an automatic circuit-breaker or by a fuse and switch. On two-wire ground circuits, the ungrounded wire should be protected by a switch and by either a fuse or an automatic circuit-breaker. If the circuit-breaker trips free from the closing handle the switch may be omitted. On three-wire circuits each outside wire should be protected by a fuse or automatic circuit-breaker, but no fuse or automatic circuit-breaker should be used in the neutral wire. A triple-pole switch to isolate the fuses or circuit-breakers from a live source should be used. If circuit-breakers are employed, they should be so arranged that the opening of the circuit-breaker in one wire will cause the other circuit-breakers to trip.

33. Suggested practice for switchboard installations.

When electrical control apparatus is mounted on a single panel it is possible to install the panel against the wall, but when the apparatus is mounted on two or more panels the following rules for space about the board should be followed:

(a) Switchboards should be so placed that there shall be a straight passageway of not less than 3 feet in width in front and back. These passageways should be clear of all apparatus mounted on the board and should be kept free of all obstructions. The space back of the switchboards should be provided with 3-foot exits at both ends, but should not be entered by an unauthorized person and should not be used for the storage of material or clothing.

(b) The space behind switchboards where the voltage exceeds 300 volts should be kept closed by locked doors that can be opened from within without the use of a key, but from without with the key only.

(c) Where the voltage of the power supply exceeds 650 volts, the live high-voltage metal work on the front of the switchboard should be guarded within 7 feet of the floor. In case of existing installations that do not meet the requirements in respect to passage space behind the switchboard, no person should be permitted back of the board while any apparatus or circuits connected therewith are alive.

(d) Conductors should not cross the passageways back of switchboards except below the floor or at a height of $6\frac{1}{2}$ feet above the floor.

34. Inspection of transformer installation (surface).

Surface transformer stations should be fenced in andprovided with doors which should be kept locked except when entered by authorized persons. Transformers should be protected by lightning arrestors. The transformer casings should be grounded.

35. Inspection of transformer installation (underground).

Underground transformers should be installed in fireproof rooms so designed that in case of fire the burning oil would be kept within the room. The room should be provided with fireproof doors that will automatically close in case of fire. Transformer casings should be grounded. Each installation should be provided with cut-out switches in the primary which will permit cutting all power off the transformers when it is necessary to do any work on them. High-tension cables feeding transformers should preferably be encased in steel armor and where feasible should enter the mine through boreholes at a point near the underground station so as to do away with the necessity of carrying the high-tension cable any considerable distance through the mine. Where this is not feasible, extreme care must be taken to protect the cable from falls of roof or other mechanical injury. A high-tension cable properly installed should offer less danger than a low-tension circuit improperly installed. The oil should be replaced each year unless chemical and electrical tests show that it can safely be used longer.

36. Inspection of battery-charging stations (underground).

More underground battery-charging stations used for charging storage-battery locomotives are found in mines as the use of these machines is extended. Such stations should be fireproof and installed where a supply of fresh air ample for ventilation can be obtained. Batteries should never be recharged in a gassy part of the mine. The best installation includes spur tracks which can be isolated from the main return for each locomotive, thereby avoiding the danger of grounding the outfit while charging. To transmit power for charging the batteries, a heavy insulated cable is used between the charging panel and the locomotive. In many installations an automatic cut-out is provided which shuts off the power when charging is complete. Each locomotive should be provided with an ampere-hour meter. Open lights should never be allowed in a charging station; also no metallic material of any kind should be allowed to lie or fall across the cells and thereby short-circuit them.

37. Inspecting stationary electric lamps (underground).

Stationary lamps such as are installed at the bottom of shafts, along sidings, and in underground rooms and stations should have their bases and receptacles made of nonmetallic material, should be well supported and, where there is likely to be excessive bulb breakage, should be provided with wire lamp guards. Lamps should not be installed near flammable material or such material stored near a lamp. Where feasible, it is preferable to use 110-volt circuit for lighting installations rather than series lighting with two or more lamps. The wiring to stationary lamps should be put in a conduit or on insulators and have the same care and attention as power circuits. The lamp bulb should not be allowed to rest against timbers or wood of any kind, and should not be covered with improvised shades.

38. Inspection of semiportable electric lamps (underground).

Around repair pits, machine shops, etc., it is a common practice to use semiportable lamps--lamps with a short extension line--which gives them a limited range of movement for inspection purposes. Such lamps should have extra flexible cord especially designed for this usage and should always be provided with an insulated handle at the lamp to which is attached an adequate wire guard.

39. Inspection of portable electric-lamp installations.

Wherever portable electric lamps are used a lamp house should be provided in which the lamps can be kept when not in use. Such houses should be arranged to facilitate receiving and giving out the lamps. Each lamp outfit should be numbered and given out to the same person day after day in order that misuse of the lamps may be traced.

A suitable and durable charging equipment should be installed at the lamp house to take care of the daily charging of the batteries. The lamp house should be in charge of a trustworthy man competent to look after the charging of the batteries and the necessary repair to the lamps.

The lamp-house man should permit no substitution of parts to be made in permissible lamps, such as charging the standard bulbs or lenses for those of another type. Lamp cords should be kept in good repair and the reflector and front glasses should be kept clean. Leaky batteries should not be allowed to leave the lamp house. The attention of the proper official should be called to any misuse of lamps or tampering with locks.

40. Inspection of telephones.

In so far as feasible, telephones should be installed in such places as to keep them dry and free from accumulation of gas or dust. Sufficient space should be provided around the phone so that it can be employed without hazard to the user from passing trips. The wiring of a telephone should be so installed and supported that it is not liable to be affected by power and lighting circuits or to become grounded and thus interrupt the telephone service.

41. Inspection of shot-firing equipment.

Electricity from a grounded circuit should not be used for firing shots.

Special precautions should be taken to prevent shot-firing conductors from becoming grounded or from getting in contact with other electric circuits. Only authorized persons should be allowed to fire shots with electricity in a mine.

Portable shot-firing machines should be of efficient design and substantially constructed. All such machines should be inclosed in strong, tight casings.

Primary or secondary batteries used for shot-firing should be inclosed in a well-constructed casing provided with a special form of contact plug for making the connection between the batteries and shot-firing leads. The design of the plug should be such that considerable pressure will be required to make the contact, which is immediately broken unless the plug is forcibly held in position.

There should be no exposed contacts on the outside of the battery casings.

All portable shot-firing machines should be equipped with a detachable handle, connecting plug, key, or similar approved device without which the shot-firing circuit can not be closed, and which under no circumstances passes from the custody of the person authorized to fire the shots.

No shot-firing device should be connected to the shot-firing leads until all other steps preparatory to the firing of the shot have been completed and all persons have moved to a position of safety.

Electrical Safety Work of the Bureau of Mines

The electrical section of the U. S. Bureau of Mines, which was organized in 1909 under the technologic branch of the U. S. Geological Survey and continued under the bureau after 1911, is continuously conducting research work tending to safeguard the use of electrical equipment in mines. Much of this safety work is done in accordance with published schedules which set forth the conditions of tests, establish certain standards of construction, and list fees covering the investigation. Apparatus which has passed such schedules is listed by the Bureau as permissible equipment. Permissible as applied by the bureau does not mean "fool-proof" or "neglect-proof" equipment; it refers to equipment that has been inspected and tested by the bureau and is approved as suitable for use in mines where mine gas, coaldust, or both may accumulate in dangerous quantities. Approved equipment is not designed for continuous operation in such atmospheres; no electrical apparatus should be operated in atmospheres known to contain gas in explosive proportions. However, should ventilation inadvertently be stopped, a door left open, or a brattice cloth torn down, it is believed such equipment will not cause an explosion of any surrounding explosive atmosphere which might exist as a result of any of the aforementioned events.

In a previous paper, Explosion-Proof Electrical Equipment, Reports of Investigations Serial 2398, published in September, 1922, the writer endeavored to bring out the difference between a permissible equipment and an equipment that has not had the benefit of the special attention to design, manufacture, and shop inspection given to permissible outfits. The fact that almost every outfit when first submitted to the bureau for inspection and tests fails to pass the tests without a certain amount of redesign should be sufficient evidence that the unapproved types do not represent the highest degree of safety.

Permissible equipments have both the manufacturer's and the Bureau of Mines guarantee, in the form of an approval plate, that certain safety standards have been met.

The classes of electrical equipment that are on the Bureau of Mines approval list have increased during the last three years until almost every line of work performed in underground mining is represented by one or more approvals. The classes that have been approved to January 1, 1929, are as follows: 5 types of permissible coal drills; 15 types of loading machines and conveyors; 5 types of air compressors; 20 types of mining machines; 4 room hoists; 11 portable pumps; 1 concrete mixer; 4 rockdusting outfits; 3 junction boxes; 9 permissible cap lamps; 8 permissible flame safety lamps; 6 hand lamps; 1 flash lamp; 2 methane-indicating detectors; 2 methane detectors; 8 permissible single-shot blasting outfits; 1 mine telephone; 14 permissible-type storage-battery gathering locomotives; 1 main-line haulage locomotive; 1 tandem locomotive; and 6 permissible-type power trucks.

The Bureau of Mines has schedules covering these various services, and is prepared to investigate the permissible features of any of the foregoing apparatus as soon as it shall have been designed and submitted for inspection, test, and approval. The bureau has no mandatory powers and can not force any manufacturer either to design or submit safe equipment. The ruling that safe equipment must be used in certain mines can only be issued by the proper State official, except in leased coal mines where the Government, as a lessee, becomes the owner and has reserved certain rights with respect to the safe operation of its leased properties. The bureau has issued approximately 100 publications dealing with electrical safety problems. Requests for any of these from the subjoined list should be addressed to the Publications Section, Bureau of Mines, 17th and F Streets, N.W., Washington, D. C.

Information on State electrical regulations can usually be obtained by addressing the State Mine Inspector or a corresponding official, or by addressing the Superintendent, Bureau of Mines Experiment Station, Pittsburgh, Pa. At least 33 States have electrical safety regulations in their safety codes.

SELECTED LIST OF PUBLICATIONS OF THE ELECTRICAL SECTION OF THE U. S. BUREAU OF MINES

	Type of publication	Publication No.	Date issued	Title	Price
(a)	Bulletin	46	August, 1912	An Investigation of Explosion-Proof Motors.	
(b)	Bulletin	52	Jan., 1913	Ignition of Mine Gases by the Filaments of Incandescent Lamps.	5 cents.
(b)	Bulletin	68	Nov., 1913	Electric Switches for Use in Gaseous Mines.	10 cents.
(b)	Bulletin	78	Feb., 1920	Approved Explosion-Proof Coal-Cutting Equipment.	25 cents.
(b)	Bulletin	131	July, 1917	Approved Electric Lamps for Miners.	20 cents.
(b)	Bulletin	227	1924	Flame Safety Lamps	50 cents.
(c)	Bulletin	240	1926	Electric Shot-Firing in Mines, Quarries, and Tunnels.	
(b)	Bulletin	258	1926	Suggestions for the Design of Electrical Accessories for Permissible Mining Equipment.	15 cents.
(b)	Tech. Paper	19	April, 1912	The Factor of Safety in Mine Electrical Installations.	5 cents.
(b)	Tech. Paper	79	Aug., 1914	Electric Lights for Use About Oil and Gas Wells.	5 cents.
(b)	Tech. Paper	108	Sept., 1915	Shot-Firing in Coal Mines by Electricity Controlled from Outside.	5 cents.
(b)	Tech. Paper	228	April, 1921	The Relative Safety of Brass, Copper, and Steel Gauzes in Miners' Flame Safety Lamps.	10 cents.
(b)	Tech. Paper	264	Oct., 1920	Preliminary Investigations of Storage-Battery Locomotives.	10 cents.
(b)	Tech. Paper	271	Dec., 1920	State Mining Laws on the Use of Electricity in and About Coal Mines.	10 cents.
(c)	Tech. Paper	306	June, 1922	Operation and Maintenance of Electrical Equipment Approved for Permissibility by the Bureau of Mines.	
(c)	Tech. Paper	402	1926	Safety Rules for Installing and Using Electrical Equipment in Coal Mines.	
(c)	Tech. Paper	429	1928	Permissible Single-Shot Blasting Units.	
(c)	Tech. Paper	433	1928	Experiments in Underground Communication Through Earth Strata.	

Type of publication	Publication No.	Date issued	Title
(c) Miners' Cir.	5	Oct., 1911	Electrical Accidents in Mines, Their Causes and Prevention.
(c) Miners' Cir.	29	1925	Misuse of Flame Safety Lamps and Dangers of Mixed Lights.
(a) Reports of Investigations	2211	Feb., 1921	Permissible Schedules Issued by the Bureau of Mines.
(c) do	2302	Dec., 1921	Inspection and Assembly of Flame Safety Lamps at the Mine.
(a) do	2308	Jan., 1922	Safety of Mine-Type Telephones.
(a) do	2358	May, 1922	Endurance Tests of Storage Batteries for Use in Permissible Mine Locomotives.
(c) do	2365	June, 1922	Ignition of Coaldust by Electric Arcs.
(c) do	2367	June, 1922	Official Approval of Burrell Methane Indicator.
(c) do	2371	July, 1922	Why Miners' Portable Electric Lamps Require Safety Devices.
(c) do	2383	Aug., 1922	Ignition of Gas by Electric Detonators.
(a) do	2384	Aug., 1922	Failure of Center Shots in Blasting.
(c) do	2422	Dec., 1922	The Explosibility of Methane-Air and Gasoline-Air Mixtures as Related to the Design of Explosion-Proof Electric Motors.
(c) do	2434	Jan., 1923	Permissible Electric Drills.
(a) do	2449	Feb., 1923	Bureau of Mines Approval System as Applied to Permissible Storage-Battery Locomotives. (First Complete Investigation under Schedule 15).
(a) do	2468	April, 1923	Monel Metal as a Material for Flame Safety-Lamp Gauzes.
(a) do	2474	May, 1923	Approval System of the Interior Department, Bureau of Mines, as Applied to Permissible Storage-Battery Locomotives. (Second Complete Investigation under Schedule 15).
(c) do	2481	May, 1923	Explosion-Proof Coal-Cutting Equipments Approved Prior to January 1, 1923. (Supplementary to Bulletin 78).
(c) do	2484	June, 1923	Why Not Scrap "The Davy"?
(c) do	2488	June, 1923	Who May Set Off Blasts in Coal Mines?
(a) do	2499	July, 1923	Carbon Tetrachloride Extinguishers on Electric Fires.
(c) do	2528	Sept., 1923	The Transportation of Explosives in and about Mines.
(c) do	2567	1924	The Danger of Open Lamps in Coal Mines.
(c) do	2626	July, 1924	Hazards of Electric Sparks and Arcs in Coal Mines.
(c) do	2813	June, 1927	The "Breathing" Action of Electrical Equipment.

	Type of publication	Publication No.	Date issued	Title
(c)	Information Cir.	6005	1926	Bureau of Mines Safety Labels.
(a)	do	6036	May, 1927	Questions and Answers on Bureau of Mines Approvals of Electrical Equipment.
(a)	do	6037	May, 1927	One Hundred and One Questions on Electrical Inspection in and about Mines.
(a)	do	6046	Aug.,1927	Wanted: More Detailed Reports on Electrical Accidents.
(c)	do	6068	May, 1928	Development and Safety of the Storage-Battery Locomotive.
(c)	do	6082	Sept.,1928	Safeguarding Electrical Equipment Used in Gassy Mines - European Practice: I - Great Britain.
(c)	do	6083	Sept.,1928	Are Flame Safety Lamps Suitable for Detecting Petroleum Vapors.

(a) Publication is out of print. Copies might be found in the larger general, scientific or educational libraries.

(b) Publication obtainable only from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the price indicated.

(c) Publication may be obtained free of charge from Section of Publications, United States Bureau of Mines, Washington, D. C.

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Circular No. 6099
January, 1929.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

"MUDITING" IN COAL MINES [1]

By D. Harrington[2] and F. E. Cash[3]

For a number of years the efforts of the coal-mining industry, as well as of the Bureau of Mines, have been directed largely towards the limitation and prevention of explosions in coal mines. The origin of most explosions is ignition of methane or marsh gas, but the extent and violence of these explosions depend chiefly on the combustible dust present.

The Bureau of Mines has conducted a large number of tests on the use of incombustible materials in limiting or preventing widespread explosions. The result of these tests, published in Bulletins 167 and 268 and Technical Paper 386, proves that incombustible dust can be so applied and maintained in coal mines that the ignition of the mixture of incombustible and combustible dusts, or the propagation of flame by the dust mixture, is impossible; on the other hand, experience and experiment indicate that watering methods are not reliable as a preventive of general or widespread coal-mine explosions.

This report describes the use of "mudite," a mixture of water and finely divided incombustible soil or dirt applied in some coal mines as a means of attempting to limit or prevent widespread explosions.

USE OF WATER TO PREVENT DUST EXPLOSIONS

Results of tests in the experimental mine of the Bureau of Mines on four Utah coals (see Technical Paper 386) show that these coals when pulverized and thrown into the air to form a cloud will ignite with 12 to 13 per cent admixed moisture and will propagate flame with 20 per cent admixed moisture. Although the tests mentioned, as well as long-continued observation and experience, have shown that watering methods as generally practiced, and especially watering in entries alone, will not prevent the spread of a well-developed explosion; nevertheless, the use of water at the face, on cutter bars of mining machines, and in wetting empty and loaded cars, will lessen the quantity of dust thrown into the mine air or otherwise distributed in the mine during the mining cycle and also make the dust more difficult to bring into suspension and to ignite. The use of water as indicated is to be encouraged, but dependence

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upon watering methods to prevent widespread explosions is futile.

USE OF INCOMBUSTIBLE DUST TO PREVENT COAL-DUST EXPLOSIONS

Bureau of Mines Recommendation

"To prevent the propagation of mine explosions, the Bureau of Mines, Department of Commerce, recommends rock-dusting all coal mines except anthracite mines, in every part, whether in damp or dry condition. It also recommends that rock-dust barriers be used to sectionalize the mine as an additional defence; but these should not be regarded as a substitute for generalized rock-dusting."[4]

Experience has shown that to make rock-dusting effective, all accessible parts of a mine should be rock-dusted on roof, ribs, timbers, and floor in shafts, slopes, entries, air courses, crosscuts, room headings, rooms, and pillar workings to and including the last crosscut or to within 40 feet of the face. This includes not only the parts of the mine that are being more or less actively worked, but also those parts that are temporarily or permanently abandoned, unless such places are securely sealed.

To rock-dust haulageways and leave parallel entries and rooms covered with dry coal-dust is false protection. There have been widespread explosions in so-called rock-dusted mines, and there will continue to be widespread explosions until it is realized that in order to limit or prevent explosions by rock-dusting the application and maintenance must be thorough.

Various dusts have been used for this purpose and tentative specifications for such use were published in Bureau of Mines Report of Investigations 2606. A brief summary of these specifications follows: The dust should contain not more than 5 per cent of combustible matter, and not more than 25 per cent of free silica; it should not absorb moisture to such an extent as to destroy its effectiveness as a dry dust, and preference should be given to the lighter colored dusts. The dust should be finely enough divided that all will pass through a 20-mesh screen and at least 50 per cent through a 200-mesh screen. In order to prevent propagation of flame, the mine-dust mixture should have an incombustible content of at least 65 per cent, and it is important that the floor dust, as well as the dust on ribs, timbers, and roof should conform at all times to this incombustible content.

USE OF MUD TO PREVENT COAL-DUST EXPLOSIONS

Numerous ideas have been put into effect concerning various methods of using water and of using rock-dust to prevent widespread explosions, and it is perhaps natural that among the various experiments a combination of the two methods should be tried; this is essentially what has occurred in the so-called "mudite" practice as used in some of the western States.

Mudite, as the name implies, is a mixture of shale, soil, or similar incombustible matter and water forming mud; it is applied to the ribs, roof, and timbers in coal mines as a means of allaying the dust and attempting to limit or prevent dust explosions. Mudite, like both of its constituents, has advantages

4 - Mine Safety Decision No. 5, April 7, 1927, published in Information Circular 6091, Dec. 1928.

and weaknesses as concerns its ability to prevent or to limit coal-dust explosions.

Muditing has been practiced in a number of the western coal mines for several years, but its use has been limited as to the number of mines which have adopted it or as to completeness of application to all of the surfaces of any one mine. Incompleteness of application to exposed surfaces is essentially similar to the use of both watering and rock-dusting, since there have been few, if any, mines which are or have been completely rock-dusted or completely watered.

Material

The material used with probably the greatest degree of success for muditing in the West is disintegrated Mancos shale, called locally "adobe" or "clay." It occurs in abundance under or overlying the coal beds in Colorado, Utah, and New Mexico, and in many places is passed over by mine tracks near mine entrances. At the places where this shale outcrops, the surface weathering causes the shale to disintegrate, and as a result the finely divided material can be loaded into the mine cars very cheaply.

Some companies dig, screen, and load the shale on the surface as used, and others haul the shale into the mine and store it on intake air in the summer season, then screen and reload it as used throughout the year. As dug, 75 per cent would probably pass through a one-fourth-inch screen, and an additional handling makes about 75 per cent pass through a 10-mesh screen.

In a mine where the so-called "adobe" is stored underground, it is put through a 10-mesh screen for use and the oversize is thrown back for further disintegration. The screen tests from samples collected in this mine gave 81.9 per cent through a 20-mesh screen; on a cumulative basis of 100 per cent through 20-mesh, 62.5 per cent went through a 48-mesh screen, 43.2 per cent through a 100-mesh screen, and 27.6 per cent through a 200-mesh screen.

Mixture

In one type of machine used for muditing the water is mixed with the dust in the discharge nozzle and the material is deposited in a manner similar to the action of the "cement gun." In others the water is fed into a mixing chamber, on the machine and deposition of the water-mud mixture is brought about by action identical with that of certain types of mine watering cars. The quantity of water used is governed by the operator. It was estimated at one mine that 2 to 3 gallons of water were used for each 100 pounds of shale.

In one mine experimental applications were made with the following proportions of shale and water;

1/2 to 3/4 gallons water to 100 pounds shale;
1 to 1 1/2 gallons water to 100 pounds shale;
2 to 3 gallons water to 100 pounds shale.

These applications were made with a cement gun, at 100 pounds air pressure per square inch, through 100 feet of 1 1/2-inch rubber hose with a 5/8-inch discharge

nozzle. The intention was to determine whether the quantity of water affected the condition of the "mudite" after it dried. All three applications were slow in drying due to the humidity of the mine atmosphere; even after 30 days they had not dried sufficiently to allow definite conclusions to be drawn. Indications were, however, that the application with the least amount of water would be less likely to become hard and the dry dust on the surface of the mudite coat would be more easily drawn into suspension and act as rock-dust in case of an explosion.

Machines

At least three types of machines have been used, involving two principles. One is the cement gun discharging the dust through a rubber hose at 79 to 100 pounds air pressure and introducing the water at the discharge nozzle; another is a commercial machine built for muditing using an electrically operated pump to distribute the mixture, and a third type, has been built by coal companies, using the mixing chamber for shale and water on the machine and pumping the mud through a rubber hose or discharging it through one or more fixed sprays. The last machines are built in varying sizes, and some are made self-propelling by the pump motor through a gear reduction to the trucks.

Application

The mud may be applied to roof, ribs, and timbers in varying thicknesses, varying from a very thin coat to as much as 1 inch. One operating company with a machine, locomotive and four men, applies the mudite at the rate of 200 pounds in 3 minutes operating time. In this case the operating time is about one-half the lapsed or shift time. This would make an average application of 1 ton an hour or 8 to 10 tons a shift. If the application were 4 to 6 pounds per linear foot of the average-size entry, it would be possible to complete 3,000 to 4,000 feet of entry per shift. One company reports that it has a machine of the mixing-chamber type built in its own shop, and with one man has mudited 3,500 feet of entry in 5 hours, and further estimates that one man continuously on the machine and a locomotive crew available for shifting and supplying the shale would mudite 1 mile of the average-size entry per shift. It is probable that this is an abnormal record and that the rate of progress would generally be but one-half to one-fourth of that given.

Cost

The cost of handling the shale and applying the mudite varies at different mines. Some mines screen and load the shale on the surface ready for use underground; others haul the adobe into the mine, store it, and then screen the material as it is reloaded for use in the machine; in general the material screened and ready to use costs $4 to $6 per ton. Again, there is a variation of from one to four men on an application crew and also a difference in linear feet of entry completed in a given time.

The average of the available costs from three mines is given as follows:

The cost of applying a 4-inch coat of dry adobe - surface soil - or shale to roadways of average width is about 8.5 to 10 cents per linear foot; placing surface soil on the floor is the treatment used for haulage roads on intake air in many western coal mines where the roof and ribs are to be rock-dusted or mudited.

The cost of applying mudite to roof and ribs is approximately 1 1/2 to 2 cents per square foot. Per linear foot the cost is about 25 to 40 cents, depending largely upon the height, width, etc., as well as upon thickness of coating. In general such work was done only on haulage roads with trolley line readily available for power purposes.

DISCUSSION

By the application of mudite the fine coal is removed from the ribs, roof, and timbers or is cemented in the coating. The mud tends to fill the cracks in the exposed strata, and thereby partly exclude the air. It is known that this partial sealing of roof and coal strata tends to prevent sloughing and breaking. This action aids materially in reducing dustiness of coal-mine openings where the coal is under heavy cover or has face cleats spaced fairly close together. It is believed that under some conditions the application of mudite on mine timbers will act as a preservative to some extent by excluding the air. Mudited timbers used in intake air for four years have showed no sign of deterioration when removed. A number of pieces both of sawed and bark-covered timber which had been mudited for three years were cut into and examined, and the state of preservation was good. All the timber referred to was used on intake air where the mudite coating was dry and hard and where the air was fresh and decidedly dry at all times. The preserving effect of mudite on timbers in return air may not be so pronounced; in fact, there is a probability that it may not act as a preservative, especially if the return air has passed through workings which have decaying timber.

Mudite makes a satisfactory incombustible coating in a mine and tends to make the coal ribs smooth and thereby remove many lodging places for coal dust. The length of time necessary for drying the mud coat in some workings is uncertain, as is also the probability of dry shale dust being available to aid in the extinguishment of flame in case of an explosion. Some users claim that it will dry to such an extent that the air deflection from moving trips will cause some of the dust to be drawn into suspension in 48 hours after it is applied. This probably is the case in a strictly dry intake air course, but in at least one application in the working section of a mine the mud coatings had not dried in 30 days after it was applied. In some places the coating becomes very hard in drying, and in other places in the same entry and apparently under essentially similar conditions it will dry with considerable soft fluffy dust on the surface; also, some kinds of material used in muditing tend more definitely than others to dry in a soft condition, so that incombustible dust lies on the surface like rock-dust.

In the use of mudite, as with rock-dust, the roof, ribs, and timbers must be treated differently from the floor. In using the disintegrated shale the floors should be cleaned and covered from 2 to 6 inches thick with the dry shale, and the mudite applied to the exposed surfaces of ribs, roof, and timbers. Also, as with rock-dusting, it is essential that additional coats be given the surfaces from time to time.

ANALYSES OF SAMPLES FROM MUDITED SURFACES

Some samples were collected where mudite was used on roof, ribs, and timbers and dry shale on the floors in one section of a western mine. The analyses of these samples are given in table I.

All of the samples were taken on intake air, and with the exception of Laboratory Nos. 44960 and 44961, the rib and roof samples were taken separately from the road sample at the same place.

The total incombustible material in samples where dry or wet shale had been applied was in general sufficient to prevent propagation of flame. Where sprinkling of the roadway had been done, the moisture content was not sufficient to prevent propagation, but there was probably enough moisture to make the fine coal in the roadways extremely hard to bring into suspension. The total incombustible content varied in rib and roof samples from 94.1 to 63.5 per cent and in the road samples from 83.0 to 23.0 per cent. From the two columns headed "Surface area" and "Weight through 20-mesh" it will be seen that as a rule only a very small amount of the mudite could be brushed from the roof and rib surfaces in trying to obtain a sample. In sample No. 44952 only 233 grams, or about one-half pound, were obtained from 150 square feet of surface; from a corresponding area of efficiently rock-dusted surface several pounds of dust would be secured by similar sampling methods. In sample No. 44968, 304 grams of rib dust were obtained from 15 square feet. In the latter case the material was applied dry, and in the former it was wet.

The sampling indicates that where the ribs and roof were mudited and surface soil or adobe was placed on the floor of the haulage road, in general the incombustible content was high, the quantity of available dust was sufficient, and the degree of fineness of the dust while not ideal was acceptable as to probable safety. There is, however, much question as to the safety of those parts of the mine where the ribs and roof were covered with the mudite but where the floors, covered with coal-dust, are supposed to be kept safe by watering methods alone. The moisture content of these floor dusts was below 11 per cent and the total incombustible around or less than 30 per cent, and while the amount of moisture present might aid to prevent this floor material from getting into the air in case of an explosion, on the other hand if this type of dust (less than 11 per cent moisture and 30 per cent or less total incombustible) should get into the air at time of an explosion, it would certainly aid in the propagation of flame.

Table I

Laboratory No.	Kind of Sample	Combustible	Moisture	Ash	Total incombustible	Surface area, sq. ft.	Wgt. in g. through 20-mesh	Through 20-m	Through 200-m	Remarks
44952	Rib and Roof	14.6	4.4	81.0	85.4	150	233	83.2	19.1	Intake air;very dry,hard, mudite.
44953	Road	42.7	3.3	54.0	57.3	15	613	83.9	39.4	Intake air;dry adobe natural state.
44954	Rib and Roof	33.6	3.5	62.9	66.4	100	440	81.9	34.7	Intake air;very dry,hard mudite.
44955	Road	58.7	3.6	37.7	41.3	12	590	81.9	41.3	Intake air;dry adobe,natural state.
44956	Rib and Roof	36.5	4.9	58.6	63.5	100	245	84.8	27.7	Intake air;dry;hard to medium.
44957	Road	77.2	10.8	12.2	23.0	24	337	35.8	5.7	Intake air; coal sprinkled, moist to wet.
44958	Rib and Roof	21.9	4.2	73.9	78.1	140	517	82.6	13.5	Intake air,dry,hard, and soft mudite.
44959	Road	69.9	9.8	20.3	30.1	20	171	15.5	10.2	Intake air; coal sprinkled, moist to wet.
44960	Rib and Roof	10.9	3.2	85.9	89.1	56	291	91.5	34.2	Adobe applied to coal ribs and roof by hand; dry, 8# linear 7x10 entry ft.
44961	Rib and Roof	19.2	6.6	74.2	60.8	50	328	79.4	14.7	Intake air;dry;mudite, hard to medium.
44962	Rib and Roof	35.6	9.9	54.5	64.4	60	216	77.4	18.0	Moist; mudite, soft.
44963	Road	73.7	9.5	16.8	26.3	20	185	30.3	5.2	Coal sprinkled; natural.
44964	Rib and Roof	17.9	3.4	78.7	82.1	40	220	81.5	18.4	Moist; mudite soft.
44965	Road	33.1	2.5	64.4	66.9	10	500	83.2	40.2	Adobe; dry.
44966	Rib and Roof	16.0	3.2	80.8	84.0	60	345	81.6	24.0	Mudite; hard, very dry.
44967	Road	16.8	2.5	80.7	83.2	12	444	81.6	25.0	Adobe; dry.
44968	Rib and Roof	5.9	2.4	91.7	94.1	15	384	73.8	23.9	Dry;mudite with dry adobe applied.
44969	Road	16.7	2.5	80.8	83.3	6	291	78.0	28.5	Dry; adobe.
44970	Rib and Roof	6.0	2.7	91.3	94.0	18	315	84.9	20.4	Dry;mudite with adobe applied.
44971	Road	19.3	2.6	78.1	80.7	6	511	81.0	21.3	Dry; adobe.
44972	Shale or Adobe	3.6	3.0	93.4	96.4	-	511	81.9	27.6	All through 10-mesh as used; dry.

CONCLUSIONS

1. Muditing is an attempt at effecting a combination of watering and rock-dusting methods for the prevention of widespread explosions in coal mines.

2. The mud coating is generally applicable only in or fairly close to entries or workings having track and readily available power lines.

3. Muditing is not readily applicable to rooms, whether working or abandoned, nor is it readily applicable to pillar workings; it does not lend itself to protecting all accessible surfaces in mines.

4. The mud mixture tends to remove or cement loose coal dust which lies upon ledges or in crevices.

5. The air-slacking of coal ribs or roof is lessened by the use of mudite.

6. The mud coating can be made an effective aid in the elimination of ledges, etc., which ordinarily act as lodging places for fine coal-dust.

7. In intake air the mudite coating on timber acts to some extent as a fire retardant and probably as a timber preservative.

8. Some kinds of soil, disintegrated shale, or similar material when used in muditing, dry in a comparatively soft fluffy condition, and hence give results somewhat similar to rock-dusting; however, most types of soil or of similar finely divided incombustible material when used as in muditing form a hard coating almost analogous to cement upon drying; hence these types of material give a minimum of effectiveness as preventive of widespread explosions.

9. A second coating of some incombustible materials used in mudite may in some cases give better results than a single coat as to the softness, hence the availability, of the incombustible material adhering to the exposed surfaces.

10. Samples from some mudited surfaces with subsequent analyses indicate that in the cases sampled too little incombustible dust would be readily thrown into the air to aid in limiting an explosion; however, in general, analysis shows that the incombustible content of the material sampled would be sufficient to prevent dust ignition or propagation if the quantity of the mudite dust were sufficient.

11. The sampling and analytical work done in connection with mudited surfaces indicate that unless the floor of mudited haulageways is treated separately by watering or by dry rock-dusting, a dangerous condition is likely to occur in connection with combustible floor dust.

12. Where mudited haulageways, especially those in intake air, have the floor kept thoroughly watered, it is probable that these places are reasonably safe against coal-dust ignition or propagation; however, cessation of floor watering for a comparatively short time (possibly a few days) would very likely result in a dangerous condition.

13. Where the floor of a mudited haulage entry is covered with incombustible material such as surface soil - the "adobe" of the West - or disintegrated shale, it has been found by sampling and analysis that if the spilled coal is kept reasonably well removed the incombustible in the floor dust can be held to a reasonably safe percentage. Hence, where mudite is used on the ribs, roof, and timber of intake haulageways, it is advisable to have the floor kept well covered with adobe, soil, rock-dust, or similar incombustible material.

14. While muditing is probably more dependable than watering, especially in haulageways which also act as intake airways, it is probable that adequate rock-dusting methods would in the long run be more dependable and less expensive.

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DEPARTMENT OF COMMERCE -- BUREAU OF MINES

ELECTRICAL ACCIDENT PREVENTION[1]

By L. C. Ilsley[2]

PREVENTION OF ELECTRIC SHOCK

The first thing to consider in prevention of electric shock is the voltage of the circuit. No person can be sure that he will not be killed, even from a 110-volt circuit, if he makes proper contact with the circuit so as to cause the maximum current to pass through his body. As the voltage is increased to 250 volts, 500 volts, or 2,300 volts the danger from contact with the electric circuit is increased. Alternating current of the same nominal voltage is possibly more dangerous than direct current. Experience has taught us that both will cause death, and that if the fatalities from this source are to be kept low, certain precautions in the guarding of circuits must be observed.

Safeguarding Surface Machinery and Apparatus

The frames of electric motors installed on the surface should be grounded to prevent shock in case they become charged with electricity because of the breaking down of the insulation. Where there is danger of accidental contact with live or moving parts, such parts should be isolated by suitable guards. This rule applies to transformers, high-voltage connections back of switchboards, etc. Trolley circuits, also feeder and lighting circuits, should have sufficient clearance from the ground to prevent accidental contact. If this is impossible, these circuits should be protected by adequate guards. Workmen or attendants who work on or around live electrical machinery should be protected by insulating mats, or by other equivalent means, to prevent serious results in case of accidental contact with live parts.

Safeguarding Underground Machinery and Apparatus

Owing to lack of space, moisture, insufficient light, etc., it is more difficult to safeguard the underground worker than the surface employee. All underground stationary motors, switchboard frames, and metallic casings of electrical parts should be permanently and effectively grounded. Portable

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motors whose frames are not in intimate contact with the earth should likewise have such frames grounded. Sub-stations and other places where it is dangerous for man to loiter should be fenced off, and only such men as are required in the routine work of the mine should be permitted to enter such enclosures. The maximum feasible clearance should be afforded all circuits, and, in so far as practicable, electric circuits should be run on one side of the entry only. Where men have to work or travel under trolley wires or other circuits, such circuits should be guarded. When men are working on an electric circuit, precaution should always be taken to insure that such circuits shall be dead and can not be unexpectedly made alive by the closing of the switch.

One of the recent steps towards safety is the wireless mine. Although the chief idea in keeping all wiring out of a mine is to prevent explosion hazards, there is also an advantage from the standpoint of electric shock. Several larger operators already have taken steps towards using storage-battery locomotives for all classes of work, thus doing away with any permanent wiring inside the mine. In such a mine there could be no deaths from overhead trolley or feeder circuits, a type of accident that accounts for a large proportion of the electric shock fatalities in the present-day mine.

PREVENTION OF GAS IGNITION

There are three conditions which make possible a gas ignition from an electric source in a mine: (1) An accumulation of explosive gas; (2) a flash or arc from an electric circuit or machine; and (3) a flash or arc taking place at the point where the accumulation of gas has occurred, or at some point to which the gas accumulation has been moved by air currents or other means. The amount of gas accumulation which is necessary for ignition lies between the limits of 5 to 15 per cent methane. The quantity of spark or flash necessary is exceedingly small; for instance: a tiny spark from a small hand-operated blasting machine is sufficient; the heat stored by the glowing filament of a 2-volt, 1-ampere bulb is likewise sufficient; the tiny spark given off by the commutator of an electric coal drill under no load has been found to ignite gas readily; the spark from the usual mine incline signalling wires has ignite gas; and the spark from most of the mine telephones in use will also furnish sufficient heat to ignite gas.

Accident prevention, therefore, means the keeping of any tiny spark or flash away from the place where any possible accumulation of gas may occur. Electrical apparatus approved by the U. S. Bureau of Mines for use in atmospheres which may inadvertently contain gas in dangerous proportions is safeguarded in various ways. Electric lamps of permissible types are provided with a bulb-ejecting device which throws the bulb out of contact in case the bulb glass is broken, thus cooling down the glowing filament and preventing it from igniting any surrounding gas. The spark-producing parts of electric motors are so enclosed that any sparks or flashes produced within the equipment during operation will only ignite mixtures within the compartments; the compartments themselves are so designed that flames are retained within the compartments

in which they originate and any gaseous mixtures in the surrounding atmosphere remain unexploded. Approved shot-firing devices are so designed that the spark produced in their operation will not ignite gaseous mixtures.

Substandard Explosion-Proof Equipment

In many mines there is a great deal of apparatus which may, from the standpoint of safety, be considered substandard. Much of this equipment, although built along explosion-proof lines, would allow flames to pass through the joints, and from the Bureau of Mine's standpoint it falls considerably short of the standard now set for explosion-proof equipment.

The advantages of permissible equipment are as follows:

Permissible compartments are subjected to actual tests to prove their mechanical strength; tested in gas to prove their ability to retain all flames within the enclosure; inspected to insure that they have no through openings into their interior; and examined to see that all bolts are in place and securely fastened. Permissible compartments also receive special attention with respect to entrance of all wires. This point is frequently overlooked in unapproved equipment.

These permissible equipments are constructed in accordance with drawings held on file with the U. S. Bureau of Mines. To retain permissibility their design can not be modified without due consideration of the effect of such changes on safety. They receive special attention while being manufactured. Most companies have special factory inspection sheets to be filled out at the factory for each approved machine, listing numerous points that need specific attention. As the purchaser of permissible equipment has made a special effort to get the safest equipment procurable he will take greater interest in seeing that it is properly operated and maintained. Every permissible machine is provided with an approval plate which identifies it as a product approved by the Bureau of Mines.

PREVENTION OF DUST IGNITION

At the present time more attention is being given to coal-dust propagation of explosions than to any other line of hazards. This is rightly so because of the extent of the havoc and disaster which may result from extension of an explosion by coal-dust. Sufficient attention has not been given to the rapidly extending hazard of initiation of explosions by coal-dust in conjunction with an electric arc, even where no explosive gas is present. The condition which is favorable to a coal-dust explosion of electric origin is a dense dust cloud in the presence of an electric flash. A dense dust cloud can occur in various ways; for example: a fall of coal or rock may stir up dry dust on the sides or bottom of the roadway or close to faces where electrically operated machinery is in use; a runaway trip may knock down timbers and release stored dust; a blow-out shot may raise dust in the room; a coal-cutting machine or a loading or conveying machine operating in dry coal beds may in their regular daily operation create clouds of dust; where dry coal is dumped on a belt, into a hopper, or into a car a dust cloud will probably result. In fact, there are few places in mines where electrical machinery is in operation that there is not danger of dust ignitions from electric arcs.

An electric flash may occur from a broken lamp bulb, the operation of a fuse, the operation of a circuit-breaker, or a switch, from the flash of commutators, the arc of a trolley wheel, the arc of a broken trolley wire, light wire, or feeder circuit, from a short-circuit of a lighting or feeder circuits, and in many other ways too numerous to mention. Fortunately for the safety of mines, the coincidence of an electric flash in the midst of a properly constituted dust cloud occurs infrequently, or else mining would be much more hazardous than it is now. However, some very bad disasters have been attributed to this combination of circumstances; two of the most disastrous were attributed to runaway trips on slopes which stirred up dust clouds and at the same time damaged the electric wiring so that dust explosions occurred which resulted in death tolls of 90 and 120 men.

Indirect Hazard to be Feared Most

The greatest danger from a dust explosion is not the direct ignition but the indirect ignition--that is, whereas it may be difficult to get just the right combination for an electric ignition of coal-dust, it is comparatively easy to ignite a small pocket of gas; under some circumstances as small a quantity as 100 cubic feet of an explosive mixture of gas and air may be sufficient to start a widespread explosion with coal-dust as the propagating or extending medium. The ignition of such a quantity of gas may in turn stir up enough dust to continue the explosion throughout the mine and be several hundred times as disastrous as the gas explosion alone would have been.

In looking for a preventive of dust explosions one must therefore eliminate not only direct ignition of dust by electric arcs, but also prevent gas ignition at the working face. If gas ignitions do occur, the dust throughout the mine should be so thoroughly saturated with moisture or rendered inert with noncombustible material as to be incapable of carrying on the explosion.

The Bureau of Mines is working in many ways to prevent coal-dust explosions. Recommendations are published from time to time covering regulations for electrical installations; flame safety lamps and electric lamps are tested for practicability and safety and are recommended for replacing open lights; electric shot-firing is advocated for all mines; motors for various services, storage-battery locomotives, and flame safety lamps are investigated to determine their safety for use in dusty atmosphere--that is, although these equipments are chiefly tested in gassy atmospheres, certain of the tests are made in dust-laden atmospheres to insure their safety in dusty mines; and finally, great emphasis is being given to the necessity and advantage of rock-dusting in order that the condition for ignition of coal-dust shall be absent.

EXPLOSIVES HAZARD PREVENTION

In present-day mining, electricity, and the successful handling of explosives are closely associated. The electric method, by means of the electric detonator, is becoming popular for firing shots. Some electrical means must be had for producing the current to heat up the bridge wire of the detonator. A number of electrical problems are involved in getting this electric current to the detonator in the amount needed, when it is needed, and in keeping it away from the detonator at all other times.

An electric detonator may require only 0.35 to 0.50 ampere to fire it, so that there must be no stray amperes loitering in rails, pipes, coal ribs, etc., where they may come in contact with the ends of detonator wires; neither can one be careless with these ends when near an electric circuit, no matter how low the voltage or seemingly insignificant the circuit may be; it is advisable that the ends of all detonator wires be twisted together or otherwise short-circuited on the surface before they are taken into the mine, and that this "short" be maintained until just before actual blasting is done. Carry all detonators to and from the mine in insualted boxes, and when about to use them still take care that the ends do not come in contact with live electric circuits or apparatus.

As black blasting powder is readily ignited from an electric flash, great care should be used to keep powder containers away from electric wires or apparatus, and especial care should be used in transporting black powder in mines containing electric wiring. All powder should be transported in special cars or boxes so constructed that the inside of the compartment is free from metal such as nails, scres, or bolts which might carry an electric current to the powder container. Notall blasting machines are safe for use in gassy mines. Machines satisfactory for single-shot unit which are on the Bureau of Mines permissible list have been tested for use in gassy atmospheres, and they do not give a spark that will ignite methane. Even the small hand-operated blasting machines commonly used for firing from one to three shots are capable of producing a spark that will ignite gas, hence it is unsafe to fire more than one shot at a time when using any type of electrical blasting machine where explosive gas may be present.

Permanent lines used in electric shot-firing should be kept away from other electric circuits and where they extend outside the mine they should be protected from lighting discharges. Ample switches should be provided for keeping the circuit open, except when the shots are being fired. Well-insulated rubber-covered wire should be used for temporary and portable shot-firing lines to minimize the danger of premature shots due to the contact of the line with other circuits.

The bureau's attention has been called to the overheating of detonator leg wires as a source of gas ignition. A preliminary investigation of the hazard resulted in the following recommendations: (1) Connect the detonators in parallel-series, series-parallel, or straight series; (2) limit the time length of connection to the firing supply to from 0.2 to 0.15 second; (3) use electric detonators with copper leg wires; (4) use a firing current supply having the lowest standard voltage that will satisfactorily fire all of the detonators as connected - for example, do not fire from a 600-volt circuit if 220 volts would be ample to give at least 2 amperes through every detonator; (5) use an ungrounded firing circuit.

In any shot-firing system the circuit should be so arranged that not less than 1.50 amperes will pass through the bridge wire of the detonator; although less current may fire a given detonator, different detonators vary in

resistance and there should be sufficient surplus current to surely fire any and all of them.

PREVENTION OF ELECTRIC-HAULAGE ACCIDENTS

Haulage accidents rank second in their toll of life and limb, being only exceeded by accidents from falls of roof.

In the old days of animal haulage the rear motive works of the mule accounted for many accidents. In modern mining the mule is being replaced by the electric locomotive, the electric hoist and various kinds of belt conveyors. The tremendous increase in speed effected by electric transportation methods as compared to animal haulage accounts in part for the high percentage of accidents charged to transportation. Haulage accidents underground are more numerous than those above ground partly because of the number of men involved and partly because of the natural difficulties encountered in underground workings, such as lack of light and space.

From the bureau's accident statistics it is found that 360 fatalities occurred underground in the year 1925 and 431 in the year 1926 from mine cars and locomotives, while 40 and 50 occurred on surface for the respective periods. Although these accidents were not segregated as to type of haulage, a large proportion of them were connected with electrically propelled cars or locomotives.

Some causes of haulage accidents are: wrecks due to trips jumping the tracks or to the breaking of rope or couplings, tripping and falling under cars and locomotives, getting squeezed between cars or between a car and the rib or roof, making flying switches or pushing cars instead of pulling them, and numerous other practices and conditions most of which are unnecessary.

Suggestions for Improvement

The following suggestions are offered as partial remedies for reducing electric-haulage accidents: (a) Provide and maintain good brakes on all haulage equipment; (b) provide and maintain good road beds, ample weight of track rails, and suitable frogs and switches; (c) provide and maintain in proper condition a separate travelway for the men; keep the roadway clean from rib to rib; (d) where men must travel on haulageways, provide sufficient plainly marked manholes and maintain proper means of access to them; (e) provide well-lighted roadways; (f) provide and maintain ample clearance to one side of the roadway; (g) keep the timbering in good condition; (h) provide and maintain tail-lamp signals on all trips; (i) provide and maintain ample headlights; (j) provide runaway switches on all slopes and planes; (k) provide, maintain, and use gongs on all locomotives; (l) prohibit excessive speed; (m) enforce discipline in regard to riding locomotives, loaded cars, cages, trips, etc.; and (n) prohibit the making of flying switches and eliminate the pushing of trips of cars.

A firm roadbed with ample clearance at least on one side, and a well-kept, properly manned rolling stock will go a long way toward reducing haulage accidents. Instruction in accident prevention and proper discipline needs to be kept up if the best results are to be obtained. Conditions in a mine will never reach any high degree of safety until the safety idea has been sold to the man higher up.

MINE-FIRE PREVENTION

Next to open lights, electricity is most dangerous as a source of mine fires. There are many ways in which electric circuits or apparatus may bring about a fire. Any machine which is overloaded or which has become worn out in service may break down, causing electric arcs and flashes capable of igniting any inflammable material close at hand. Every electric circuit is a possible source of fire hazard. Circuits can cause flashes when the wiring becomes grounded, when the circuit is opened under load (accidental separation of wires by fall), and by the short-circuiting of wires of opposite polarity.

Certain apparatus such as switches, fuses, and circuit-breakers flash and give off arcs under normal operation. Oil-filled apparatus is especially dangerous if the oil once becomes ignited because of the failure of the apparatus. Stationary electric-lamp bulbs may start a fire from the heat generated if they are installed too close to inflammable material.

Good Installation the Best Safeguard

Many of the foregoing dangers are cured by proper installation of apparatus and circuits. All electric machinery should be installed in spacious, well-supported, fireproof rooms and on substantial fireproof foundations. Insulators should be placed close enough together to keep the wires from touching coal, rock, or timbers. Wires should never be run over timbers or placed where they can not be readily inspected. Temporary wiring should be discouraged; at any rate, temporary wire installations should be replaced within a few days by safely arranged permanent installations. Stations containing oil-filled equipment, such as transformers, should be so arranged that if for any cause oil is spilled it will not escape from the room. The room should have suitable fireproof doors which when closed will quickly seal the area.

Protection from Overloads

All circuits and apparatus should be of sufficient size to perform their work without overheating and should be protected by circuit-interrupting devices against sustained overloads. Automatic reclosing circuit-breakers are proving successful on the main-line circuit, but would probably add to the fire hazard if used on branch circuits.

Cleanliness

Rooms containing electrical equipment should be kept free from inflammable material. All wiring should be kept clear of inflammable material. Fire fighting equipment should be kept in every underground station suitable for extinguishing electrical fires. Grease and oil should not be allowed to collect on or about electrical apparatus.

The Safety Side of Electrical Equipment

Although electricity for some usages in mines has added to the fire hazards, this is not true of electricity as used for mine illumination and shot-firing. The electric cap lamp has replaced thousands of open lights, which are always a potential fire hazard. Electric shot-firing, which does away with the fuse and in many cases with the open light for igniting it, also reduces the fire hazard. One chief mine inspector, in commenting on the Bureau of Mine's work states that the aid of the Bureau of Mines in developing the electric cap lamp alone is worth the whole cost of maintaining its electrical section since its inception.

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Circular No. 6101
January, 1929.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE--BUREAU OF MINES

SAFETY LETTERS[1]

By D. Harrington[2] and C. W. Owings[3]

Manufacturers have long realized the value of keeping the interest of employees focused on the products manufactured, for in so doing efficiency in the organization is maintained or even increased. One method of attaining this goal is through a publication termed a "house organ." In recent years this idea has been adopted, to a comparatively limited extent, by mine operators in an effort to obtain greater safety and operating efficiency from the bosses and the men. There are several adaptations of the "house organ" idea to mining; some companies publish weekly, monthly, or possibly every three months, a mimeographed multigraphed, or printed pamphlet devoted in whole or in part to safety; generally circulation is limited to only a portion of the employees and to a few persons outside of the company organization. Another plan is that of sending letters (mimeographed or multigraphed); it seems probable that this method carries with it the greatest amount of the "personal touch" so essential in effective educational work. This paper will treat of the letter method of spreading safety propaganda.

One type of letter (distributed weekly, monthly, or in some instances every three months) is that sent by the safety official or possibly some operating official to all foremen or bosses; another is a letter issued every week or every month, or at irregular time intervals to all employees - not only to the mine officials but to every worker in every occupation above or below ground around the mine. The letters are prepared by the safety director or engineer or by some higher official such as the general superintendent or the general manager. The value of the letter is greatly enhanced if it is contributed by the general manager, as it shows an active interest on his part in the men as well as in the mine and indicates that he is reasonably familiar with mining conditions; in fact, it practically forces him to keep in intimate touch not only with the mine operations but also with the mine itself and with the miners as individuals, or at least as human beings. The greatest value, however, is the impression given to the employees that the management is definitely behind the safety movement.

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WEEKLY OR MONTHLY LETTERS TO FOREMEN

Letters to the bosses should have a distinct place in the safety program. The message delivered can be direct and at the same time convey no criticism of the bosses to the men under them, as would be the case in the letters directed to all employees. There is a psychological effect on the bosses who see their names in the letter as having a good or bad record, especially if there is a bonus or a bonus penalty system in effect. Those having few accidents among their men strive to reduce the number still further and those whose men are frequently injured strive to attain the best record possible. Moreover, the mine boss is entitled to have placed before him in "black and white" from time to time the definite ideas and attitude of the "higher-ups" of the organization in order to have a definite basis upon which to formulate his own ideas and policies toward his work.

Some examples of effective weekly letters as issued to the foremen of the Nevada Consolidated Copper Co., Ray, Ariz., will illustrate the value of this type of letter.

> " 'Five minutes of thinking will do more than a whole night of wishing.'
>
> " Mr. Roy Walsh, foreman at the No. 2 mine, has been presented with a nice watch fob by Mr. Thomas in appreciation of the fine safety record he has been making at the No. 2 mine. Mr. Walsh worked a period of 47 days with only two minor lost-time accidents, and we feel that this record will compare favorably with most any mine in the country.
>
> " For the second quarter of the year we had three fatal accidents and 32 serious accidents. For the third quarter ending September 30, we had no fatal accidents and 23 serious accidents. The ratio of serious accidents per 1000 shifts worked for the second quarter was .374. For the third quarter the ratio was .273. That shows that the efforts of the different department heads and bosses are meeting with success, and we feel that the last quarter of the year, which we are beginning now, will show as much if not more improvement.
>
> " For the month of September at the No.2 mine, 13 bosses out of 15 were in the bonus class. That is almost a perfect score. Also it makes two months straight for 10 of these bosses to receive bonuses. Mr. Kinsey is still keeping up his good work. He has worked 9,007 shifts now with no lost time.
>
> " In the near future we expect to have the accident figures of some of the other properties of the Nevada Consolidated Copper Co. When we get those figures we will put them in the weekly letter so we will know how the Ray plant compares with some of the other properties of the company.

" Several of the jigger bosses at the No. 2 mine are making nice records and if they keep up their present rate they will have a good chance for the yearly award. The jigger bosses in the stopes should see that their men bar down before they start to drill as we have had several injuries in the past by men getting hit with falling rock while drilling.

" The motor bosses should see that their brakemen have brake sticks and they should not allow their brakemen to use their feet in coupling cars. Also, they should tell their motormen to watch the brakeman to make sure he is not going to get hurt.

" If any jigger boss wants his record for the first eight months of this year, the Safety Inspector will gladly give it to him. Also, any of the other bosses that want their record can have it.

" The last six accidents that were reported were accidents that the men themselves could have prevented, so that shows us we should talk to the men every day about working safely.

" ' Spikes and nails make poor acquaintances. TURN THEM DOWN. '

"SAFETY DIRECTOR"

There is much in the letter quoted that is well worth considering in preparing a weekly letter. In the first place, attention is arrested by an apt quotation, which will usually cause a man thinking and place him in a receptive mood to digest the text of the message. The first item of interest is the award for a meritorious safety record; this is a distinction for which all reasonably minded bosses will strive. Facts and records are then treated and achievement is commended. Before calling attention to failure of the jigger bosses, they, as a class, are commended. Finally, there is a short snappy saying in which humor is introduced to help strike home the safety thought.

All letters are not of the same general form as will be seen in the following example:

" He is free from danger who, even when safe, is on his guard.

" We had no lost-time accidents during the past week, but on November 24 a brakeman received a serious foot injury. The injured man said that he was not coupling cars with his foot, but from the appearance of the shoe and the injury of the foot it surely seems as if he was using his foot. The stories of the injured man, the motorman, and the jigger boss did not agree, which also makes us believe that the injured man was coupling cars with his foot. The motorman was given a ten-day lay-off as we feel

that he was responsible to a large degree for the accident. These foot accidents to brakemen can and must be prevented, and in the future the motorman and jigger boss will be held responsible for such accidents. All bosses should instruct their motormen to refuse to work with a brakeman that will not use his stick and the boss will give him another brakeman. We believe that the motorman knows if his brakeman is using his foot to couple cars and therefore the motorman will be held responsible if he does not tell his boss that the brakeman is not using his stick.

" We are pleased to note that some of the bosses and jigger bosses are wearing the safety shoe. Mr. R. W. Thomas, Supt. of Mines, is wearing the safety shoe during his trips underground and finds it to be very comfortable.

" During the first ten months of this year we have had 486 days of lost time from toe injuries. This does not include foot injuries such as insteps, etc., which no doubt would be prevented to some extent by the safety shoe. The 486 days lost was for toe injuries alone.

" For the period between the last two inspections of the Mining Inspector we had six serious accidents. Four, or two-thirds of these six accidents, were from falling rock. Two were in stopes, one in a drift, and one at a chute. We realize that it is next to impossible at times for a chute blaster to get his hands and feet out of the way of falling rocks, but we also believe that injuries from falling rock in stopes and drifts can, to a large extent, be overcome. In most cases, where a man is injured by falling rock while drilling in either a drift or stope, it is through his own carelessness or the carelessness of someone else.

" 90 per cent of all accidents are avoidable; so by thinking before the accidents occur instead of after they occur, a big part of these accidents can be prevented.

" Don't forget to impress on your jigger bosses and motormen that they will be held responsible for foot injuries to their brakemen.

" ' He who stumbles twice on the same stone deserves to break his neck.'

"SAFETY INSPECTOR."

As in the preceding letter, the opening sentence is arresting. The men learn to expect such an opening to the letter and then will read the entire message rather than lay it aside. There is an important message in this letter in that there was a careless accident, probably in violation of one of the rules.

The case is cited, responsibility is placed, and the guilty ones are punished. All bosses who read this short statement will realize that safety rules must not be broken, and after each man returns to his section, he will warn the motormen and jigger bosses to obey all rules. The rule requiring men to wear safety shoes is shown to be practicable, and that it applies to all men including the bosses. The example of the superintendent wearing the shoe shows, further, that the management is sincere in the desire to reduce toe and foot injuries. The concluding sentence in the letter drives home a safety thought with a smile. These contacts with the bosses contain much to commend them to every mining company in the United States.

LETTERS TO ALL EMPLOYEES

The bosses in any mine form only a small proportion of the underground personnel; therefore, to keep in contact with the men, a letter should be directed to all employees once a week, once a month, or possibly at irregular intervals when there is a definite message to be transmitted to the employees. Such letters should not be long, should not cover too many subjects, and should be written in simple readily understandable language. It is of decided advantage to discuss only one subject or accident in any one letter. The United States Coal and Coke Co. at Gary, W. Va., sends letters from the general superintendent to all employees, and as the form of these letters is very good a few will be quoted; these letters are delivered by the company to each worker at his working place. The safety record of the coal mines of the U. S. Coal and Coke Co. at Gary, W. Va., is so good that coal mines elsewhere may well study Gary methods with adoption of them where at all feasible. One of the mines of the U. S. Coal and Coke Company at Gary, W. Va., was given the J. A. Holmes Safety Association certificate of honor for having worked 606,072 underground man shifts and 214,667 surface man shifts from February 24, 1917 to December 31, 1926, producing 6,030,862 short tons of coal, without a fatality. This safety record has seldom been equalled in the United States.

Below is copied one of the letters delivered to workers at working places at Gary mines:-

"To all employees:

"Thomas Mechugar, coal leader, 53 years old, Slavish, married with four children, was seriously injured at No. 2 Works on Wednesday, November 9th, at 8 a.m., by fall of coal.

"Mechugar and two other loaders were in No. 20 room off 7 left loading bone from the gob for the Power Plant. He was loading the bone that was piled against the rib when a large slab of coal fell from the rib without warning, and struck his leg, breaking it just above the ankle.

"This accident is unfortunate for the man and for No. 2 mine, inasmuch as this is the first TIME LOST injury that has occurred in that mine during 1927.

"The safety committee, after hearing the evidence, decided that the injury was caused by the fact that the injured man was in too big a hurry to load his car and did not pay attention to the dangerous condition which existed in the place he was working.

"It is to be regretted that such an accident should happen in order to call forcibly to everybody's attention the fact that they must not let their desire to earn money during this slack period make them careless and neglectful of their safety.

"Investigation of the accident further brought out the fact that the assistant mine foreman had not examined the rib from which the coal fell, although he knew it was loose and he had not specifically instructed the man as to the danger in his working place. He had exercised extreme care in the past, he had a 32 months' record when the accident occurred. This record was considered when he was only reprimanded instead of being discharged or suspended.

"Very truly yours

"General Superintendent"

This letter, as will be observed, deals wholly with one accident. It describes the manner in which the injury was received, the cause of the accident, discusses the surrounding circumstances and conditions, and places the responsibility. There is one important point to note carefully; company responsibility through its officials is not "<u>dodged</u>," and the assistant mine foreman, although adjudged to blame, was only reprimanded because of his excellent past safety record. In other words, it is indicated that safety records will be commended and rewarded, but that no mercy will be shown the careless workers, including mine officials. This is shown in an excerpt from another letter, describing another accident.

"The investigation of the accident disclosed that the injured man was standing between the car and the rib as it was being pulled, and was struck by the car as it was being rerailed. The assistant mine foreman was in the place and observed the fact that this man was in a dangerous position, but failed to remove him before attempting to rerail the car. The investigation further disclosed a lack of discipline and also the fact that proper instructions had not been given by the mine foreman. It was felt by the Investigating Committee that the accident was the result of an accumulation of deficiency on the part of the mine organization, and as a result, upon their recommendation, the mine foreman as well as the assistant mine foreman were permanently removed from their positions.

"In this connection we wish to state that it is our opinion that practically all our accidents are directly traceable to lack of discipline and to disobdience of rules. We wish further to state that the officials of the mine, including the safety inspector, mine foreman, and all assistant mine foremen will be held strictly accountable for accidents which occur under their jurisdiction, but trust that there will be no further necessity for actions such as were taken in this case."

The position of the management in regard to the enforcement of safety rules is not left in doubt, and it is readily understood that the policy of the company is to let "safety" be "the first consideration." Each letter has at the top the caption:

SAFETY THE FIRST CONSIDERATION,

and at the bottom the following:

THE PRODUCTION OF COAL WITHOUT FATALITIES,
IT CAN BE DONE.

The safety letter idea was carried even further by the general superintendent. He requested his men to send in letters on safety. Some of these were copied in the weekly letter. The value of this plan is shown in the following abstract from a letter submitted by one of the bosses:

"Now, I will say for some of us Bosses - some of us talk to our men as if we had our head in a sack, and did not want them to see who was talking, as if to say that 'this is just merely a rule and it was handed to me, and I am handing it to you, and don't say I haven't told you.' Take time, explain the Rule, and show the man where it is good for him to obey it; for himself and for the company. What is good for the Goose is good for the Gander. An old saying, and it is right in this case. If the company makes good return on money invested, they can pay the men better, and if he takes chances, and gets killed, he has cost his family money and sorrow."

Still another means of stressing safety is contained in the following letter:

"To All Employees:

"While visiting one of our plants last week, I noticed in the wash house a miner who was bathing himself very carefully. He was extremely particular, even cleaning his finger nails.

"I inquired of the superintendent about this man, and the superintendent told me that this miner was just as particular in his working place and in his home as he was in his personal habits. His home and surroundings are kept neat and clean, and

his working place in the mine is always in first-class order. I was advised by the superintendent that this man is one of the best and most careful workers in the mine. In fact, he says he can almost always tell the kind of miner a man is by watching him as he washes himself in the wash house of the mine.

"It was very pleasing to find this particular man, and I presume there are other men at our plants who are using to good advantage the facilities for washing that we have furnished them. The wives and families of the miners are undoubtedly pleased to have their husbands and fathers come home clean and neat.

"I am sorry to say that I noticed some of the miners were not at all particular, and did not take advantage of these facilities, and when they had finished washing were about as grimy as when they began.

"I hope all of our miners will learn to avail themselves of the bath houses that we have furnished for their benefit, as we believe that a man who is particular about his personal habits will be particular about his health, and will also be particular about his safety in the mine, and avoid getting injured.

"Yours very truly

"GENERAL SUPERINTENDENT"

About twelve hundred of these multigraphed letters, each giving a different message, have been sent from the general superintendent to each of the U. S. Coal and Coke Co.'s employees at Gary, W. Va. Although every letter carries the safety captions heretofore mentioned, some of them are concerned largely with efficiency, or convey some thoughts on patriotism, good citizenship, or give information as to mine gases or dusts, or something of a similar nature. The letters herewith quoted deal chiefly with critical analyses or statements concerning accidents, yet many of the letters were of a congratulatory nature when calling attention to the good safety or efficiency record of a mine, of an official, or of an individual employee. There is no question that this type of contact work by the mine management in taking all of the individual employees into its confidence has a good effect not only as to safety but also as to efficiency and as to kindliness of feeling between employer and employee.

The system of sending letters from high mine officials to employees, discussing matters of company policy, - efficiency as well as safety - outlining the attitude of the company, giving reasons for actions taken, and indicating what is expected not only of the general run of employees but also of the mine officials, can not fail to have good results. The letters addressed to foremen may contain more than one subject, since the men in responsible positions are

selected because they show more than average ability and should be able to comprehend the import of things more quickly than many of the mine workers. The letter to all employees should, in general, be limited to one subject and should be more descriptive than the foreman's letter. The men should be made to feel that the "big boss" has their welfare at heart and that he not only sympathizes with them but that he also takes them into his confidence by writing them a personal letter. The opportunity to send to the workers commendation for notable achievments in safety and condemnation of unsafe practices should be grasped by every mine operator. The rewards in more satisfied workers, decreased accidents, and, as a consequence, in economy of operation will far exceed the cost and effort expended in this most excellent type of educational work.

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Circular No. 6102.
February, 1929.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE -- BUREAU OF MINES

I. MINING LAWS OF RUMANIA[1]

By John W. Frey[2]

PREFATORY NOTE

This paper presents one of a series of digests of foreign mining legislation and court decisions which is being prepared in advance of a general report relative to the rights of American citizens to explore for minerals and to own and operate mines in various foreign countries. This interpretation of the laws of Rumania, originally prepared from the best available information in Washington, has been checked, through the courtesy of the Department of State, by the American Charge d'Affaires at Bucharest (Oct. 19, 1928).

SYNOPSIS OF LAW

The mining law promulgated by royal decree (No. 2294) under date of July 3, 1924, asserts the claims of the State to ownership of practically all commercial minerals (Articles 1 and 2) and provides that these minerals shall be conserved for exploitation largely by Rumanian capital.

The ownership of all mining companies formed after July 3, 1924, must be at least 60 per cent Rumanian, and the chairman and at least two-thirds of the members of the board of directors must be Rumanian (Article 33).

Companies with foreign capital in existence prior to July 3, 1924, but which do not fulfill all the conditions of Article 33, may obtain land from the State if they will make a declaration that within the first ten years they will adapt themselves to Article 33 and modify their board of directors so that two-thirds of the directors and the chairman will be Rumanian. For such companies the requirements as to Rumanian capital are reduced to 55 per cent.

Companies existent before July 3, 1924, which then had a simple majority of the capital (51 per cent) held by Rumaniana and a majority of Rumanians on the board, may secure mining concessions from the State if they have 51 per cent of the capital in the hands of Rumanians. (Addition to Article 32 of the Mining Law, 1924, published in "Monitor Official" No. 270, December 6, 1925).

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2 - Associate mineral economist, U. S. Bureau of Mines, Washington, D. C.

Circular No. 6103
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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

II. MINING LAWS OF CZECHOSLOVAKIA[1]

By John W. Frey[2]

PREFATORY NOTE

This paper presents one of a series of digests of foreign mining legislation and court decisions which is being prepared in advance of a general report relative to the rights of American citizens to explore for minerals and to own and operate mines in various foreign countries. This interpretation of the laws of Czechoslovakia was prepared with the aid of a questionnaire submitted to the Government of Czechoslovakia through the courtesy of Doctor Papanek of the Czechoslovakian Legation, Washington, D. C.

SYNOPSIS OF LAW

The mining law of Czechoslovakia covers the so-called exempted minerals, a group which includes all minerals that may be made use of because of their content of metal, sulphur, alum, coal, lignites, etc. Except for the Government salt monopoly, prospecting and mining of such minerals is free to any one after obtaining permission from the authorities. Reciprocity being presupposed, the law makes no distinction between citizens of Czechoslovakia and foreigners. A mining permit is required for prospecting as well as for mining. A concession conveying actual ownership of mineral rights may likewise be procured under proper regulations. Permits or concessions may be issued to anyone who is capable of acquiring real property; it is not necessary even to have permission of the owner, except in Slovakia and Transcarpathia where under the local laws (formerly Hungarian) consentof the owner of the land must be obtained before prospecting or mining for coal. Even in these parts of the country, however, mining rights except for coal are generally distinct from surface rights, and the miner can, if necessary, condemn land and obtain such surface privileges as may be requisite to his mining operations.

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2 Associate mineral economist, U. S. Bureau of Mines, Washington, D. C.

Permits for mining

The permits for mining are issued by the mining office of first instance (regional mining office). The issuance of a mining permit is not dependent on any qualifications of the miner, except the capability of acquiring real estate. The State does not sell, but grants mining rights. The technical administration of mines must, however, be entrusted to a properly qualified person, who is responsible in administrative matters. The permit for mining is issued for a certain definite area, such as a specified parcel of ground, cadastral survey district, commune, or other political sub-division.

For one and the same area of ground, general mining permits may be issued to more than one operator. If a miner who has been granted a mining permit wishes to acquire the exclusive right to mine in a certain area, he must post at the mining bureau an exclusive claim. An exclusive claim is granted for an area with a horizontal radius of 425 meters. Since the grantee alone has the right to mine inside of an exclusive claim,he has as against a neighbor who asks for it, a right to the granting of a single mining concession, or in the case of coal, two concessions. As later explained, the number of concessions is raised to two or more, provided the mine workings are 94 meters or more deep, the number of concessions increasing in proportion to the depth of the work done.

The annual fee for every exclusive mining right is 24 Czech crowns. The mining license is issued for a period of only one year and does not carry with it the right of renewal. The mining bureau will extend the mining permit from year to year only if convinced that the miner has started mining work and is continuing it. The miner is required to keep the work going constantly upon his exclusive claim. If this is not done he is ordered to start operations and in some cases is punished by a fine; if the fine is not paid, his exclusive right is revoked.

A mining permit can be refused to persons who otherwise meet the legal requirements only when the mining would menace objects of public benefit, such as wells and means of providing communities with drinking water, medicinal springs, and so on. Mining along highways, railways, and waterways is permitted only with the consent of the proper authorities.

Within a distance of 38 meters from dwelling houses, farm and other buildings, enclosed courtyards, gardens enclosed by fences, land enclosed by walls, and churchyards a miner can start digging only with the consent of the owner of the land. The owner of the land is obliged to allow digging on all other lands in return for compensation, the amount of which, if it can not be agreed upon with the miner, is fixed by the Governmental authorities.

Concessions

Anybody who wishes to acquire ownership of exempted minerals occurring within the limits fixed must apply to the mining bureau for authorization and a mining concession.

A mining concession is granted only in case of exempted minerals discovered in their beds at the place for which the concession is asked, when it is considered that mining can properly be carried on under local conditions. It appears that the discovery of exempted minerals does not carry the right to mine; that right depends not only upon the kind and amount of mineral in the bed, but also upon the possibilities of using and selling it. According to the intent of the legislature, <u>the founding of those mining enterprises is to be allowed which are of value to the national economy</u>.

For the granting of mining concessions no qualifications of any kind are required except that of being capable of acquiring real estate. The technical management of the mine itself must, however, be entrusted to a person qualified in that respect - that is, one competent to manage the work. The concession is a parallelogram in a horizontal plane having an area of 45,116 square meters, the shorter side of which must not be less than 106 meters. For one discovery of exempted minerals there is granted, in the case of coal, a double concession (two concessions adjacent to each other on the long side); for other minerals one concession is granted. If the discovery is reached by a shaft 94 meters or more deep the discoverer is entitled, in the case of coal, to four concessions, or for other minerals to two concessions. By the granting of a mining concession, authorization is given to take out all exempted minerals occurring in this concession.

A concession is real property and although it may be revoked if the owner fails to comply with certain regulations it is not limited as to time. It can be sold or ceded during the lifetime of the concessionaire or by his last will. For a single concession a payment of 40 Czech crowns must be made to the State treasury. Royalties to the owner of the land are unknown in Czech mining law.

If the discoverer meets the legal requirements in other respects and if there are no reasons connected with the common weal on account of which the concession should not be granted (for example, the protection of water reservoirs, conduits, and so on), the granting of a mining concession can not be refused. The concession may be canceled if the entrepreneur, after repeated warnings and fines, disregards the regulations issued regarding the safety of persons and property or does not keep the establishment in proper operation at all times.

The concessionaire is given the right by the concession to make on the surface of the ground all arrangements necessary to the operation of the mine, and in particular to drive galleries, shafts, and passages; to erect buildings and machinery for mining, transporting, and cleaning the mineral, for pumping out and ventilating pits, and for the dwelling houses of employees; and so on. The owner of the ground is obliged to transfer to the holder of the concession, to be used by him but not to be owned by him, the ground which is needed for the operation of the mine. If the owner of the land and the holder of the mining concession can not agree concerning the transfer of the land and the compensation, the holder of the concession settles the matter by asking for condemnation. Land on which mines can not be opened without the consent of the owner are not subject to condumnation.

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Circular No. 6104
February, 1929.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

IV. MINING LAWS OF BRITISH INDIA [1]

By John W. Frey[2]

PREFATORY NOTE

This paper presents one of a series of digests of foreign mining legislation and court decisions which is being prepared in advance of a general report relative to the rights of American citizens to explore for minerals and to own and operate mines in various foreign countries. This interpretation of the laws of British India has been prepared from the best information available in Washington, but is released <u>subject to correction and amplification</u>, if necessary, by the proper American diplomatic and consular officers to whom it is being referred through the courtesy of the Department of State.

ANALYSIS OF LAW

In the absence of any long line of judicial decisions, the courts of India--when considering trespass working, subsidence, severance, and other matters that arise inevitably wherever mining on a substantial scale commences -- appear to have relied in recent years very largely on English precedents. Upon certain subjects (e.g. severance) it is difficult to follow safely English precedents so long as it is still undecided in whom mineral rights reside. Any ordered exposition or development of the law of mines in British India appears difficult until the principles of land law are sufficiently settled to enable one to determine whether or not the minerals are owned by the State. The difficulties under this head which exist at present are not mere difficulties of fact or of evidence, but are difficulties of principle.[3]

Throughout India, it is established as an administrative principle that the State has the right to minerals,[4] except in permanently settled estates or where any distinct judicial precedent or proof of established usage exists.

1 The Bureau of Mines will welcome reprinting of this article but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"
2 Associate mineral economist, U. S. Bureau of Mines, Washington, D. C.
3 Imperial Mineral Resources Bureau; "Mining Laws of the British Empire and of Foreign Countries": vol. 6, pt. I, 1924, pp. 1-12.
4 Ref. cited, p. 4.

As regards permanently settled estates, the answer to the question as to whether ownership of the minerals was vested in the State or in the grantee is still uncertain in so far as the question is one of law, but it has been decided hitherto as a matter of policy to treat the grantee as though the minerals were owned by him. As a matter of administrative practice, though not as a matter of decided law, the State grantee in the case of permanently settled estates is regarded as having the mineral rights, whether such minerals relate to gold, silver, or other mineral substances.[5]

Even where the land is of a class in which private rights in minerals exist it is not always clear as to who owns the mineral rights. The subject has, however, been made somewhat clearer as the result of a series of decisions by the Judicial Committee.

The principal difficulty arises where the proprietor of a permanently settled estate grants a permanent and heritable lease of a wide character without mentioning minerals. In such a case it was at one time thought, in India, that the grantee obtained mineral rights. It has now been decided that prima facie he does not.[6]

Granted that minerals are in the State it would appear that the rights to them vests in H. M. Secretary of State for India, and thus property in them appertains neither to a Local Government nor to any particular department. Mineral rights are ordinarily administered by the Local Government of the Province in which the minerals are situated, subject to statute or to any rules made or sanctioned by the Government of India and to the general executive control of the Supreme Government.

<u>Alien restrictions</u>

Before prospecting for minerals can lawfully be done it is necessary for the prospector to obtain (1) a certificate of approval and (2) a prospecting license. Neither of these can be obtained except by a British subject or in the case of a company or firm by a company or firm that has shown to the satisfaction of the Local Government that it is controlled by British subjects. (Ibid. p. 27.)

With regard to aliens the general rule for prospecting and mining the major minerals and mineral oils (the minor minerals generally are those not possessing high commercial value, as for example, slate, building stone, and clay throughout India, with the exception of the State of Bombay, is as follows:

A certificate of approval, a prospecting license, or a mining lease shall be granted only to a person who is a British subject, or if the person be a company or firm, only if such company or firm shows to the satisfaction of the Local Government that it is controlled by British subjects. In the case of death of the person or any other person to whom the license or lease has been granted it shall inure for the benefit of his legal representatives only if they are British subjects, or a company or firm shown to the satisfaction of the Local Government to be controlled by British subjects. (Mining Rules, corrected to 1924: Rule 3.)

5 Ref. cited, p. 4.
6 Ref. cited, p. 20.

In Bombay this rule can be relaxed and mineral concessions can be granted by the Government of India, subject to the approval of the Secretary of State for India in Council, to aliens in cases in which circumstances make this desirable and in which the concession is unlikely to prejudice the future control of the Government of India over mineral products.[7]

In Assam a prospecting license now confers on the licensee the sole right to work all minerals instead of those only which are specified in the license. In the future, however, licenses to prospect for petroleum, chromite, manganese, vanadium, molybdenum, nickel, and all ores of tungsten will be granted only to British subjects. If a foreigner is already in possession of a prospecting license for a reserved mineral, he may be given a renewal of the license or a mining lease, to which he would have been entitled under the old rules, but no fresh concessions should be given him in respect of such minerals.[8]

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7 Ref. cited, p. 44.
8 Ref. cited, p. 56.

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Circular No. 6105,
March, 1929.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

VII. MINING LAWS OF BRITISH AFRICA [1]

By John W. Frey[2]

PREFATORY NOTE

This paper presents one of a series of digests of foreign mining legislation and court decisions which is being prepared in advance of a general report relative to the right of American citizens to explore for minerals and to own and operate mines in various foreign countries. This interpretation of the laws of British Africa, prepared from the best available information in Washington, has been slightly modified in accordance with suggestions submitted by Ralph J. Totten, American Consul General at Capetown, and Glenn A. Abbey, American Vice Consul at Johannesburg, transmitted through the courtesy of the Department of State.

ANALYSIS OF LAW

British Africa as a whole is relatively open to American mining operations. By treaty, Americans have the same rights as British citizens in the Mandate of Cameroon, Togoland, and East Africa. In the Gold Coast, Ashanti, Nyasaland, and Nigeria no aliens are granted the right to explore for or exploit mineral oils; in Rhodesia diamond mining (excepting alluvial) is a monopoly of the DeBeers Consolidated Mining Corporation; and in Nigeria there is a discriminatory duty on the export of tin. In all the rest of British Africa, although exploring or mining is nowhere free, there is no apparent legislative or administrative discrimination against citizens of the United States.

Americans in common with South Africans and all other nationals are practically prohibited from prospecting or digging for diamonds, but this is because the Government, pursuing the policy of stabilizing the industry, will not issue the necessary licenses if it can possibly avoid doing so. The mining laws of the Union of South Africa have not been consolidated, and the laws passed by the various Colonial Governments are in force in the various provinces. There are no restrictions, legislative or administrative, in force in the Union that apply to aliens and not to nationals. Although the Government allows the diamond companies practically to control the mining of diamonds, this control has been acquired progressively over a number of years and is not a granted monopoly.

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2 Associate mineral economist, U. S. Bureau of Mines, Washington, D. C.

The Transvaal

The right of mining for and disposing of all precious metals is vested in the State; the ownership of, and the right of mining for and disposing of base metals is vested in the owner of the land. (The Precious and Base Metals Act, 1908 (No. 35 of 1908) with amendments, art. 1.) State land is not open to prospecting until the Minister of Mines declares it to be open. (Ibid. art. 10 (2).) There is no expressed discrimination in the law against citizens of the United States. Prospecting is not free.

Unless the prospector is the owner of the land, a prospecting permit is required and can be issued to any white person of the age of 16 years or upward (ibid. art. 14 (1)), and is in force one year (ibid., art. 14 (2)). The discovery of any mineral must be reported to the Mining Commissioner. If the Minister of Mines is satisfied that a genuine discovery has been made and that there is reasonable ground to believe that precious metals exist in payable quantities on State lands, he will give the prospector a notice to peg out a claim (ibid., sec. 17, 18, and 19). If the discovery occurs on private land, he may proclaim the land for public digging, and the owner of the mineral rights has to select one or two areas called a "mynpacht" (ibid., sec. 20). The Governor may declare the whole or any portion of proclaimed land open to the public for pegging, he may lease to any person the exclusive right to mine the precious metals, or he may, with the sanction of Parliament, establish a State mine (ibid., sec. 26 to 30). In the case of precious metals, as soon as machinery has been used for crushing or the treatment of ore, or a claim has been sufficiently developed to permit the extraction of ore, the license holder must convert his prospecting license into a digger's license whether on State or private land (ibid., sec. 40 (3)). Upon the Public Diggings open to pegging, any white person not under 16 years of age may get a permit, good for one month, to peg out from one to fifty claims (ibid., sec. 32). The occupier of a claim has to pay a monthly fee for his license to dig. The Governor has the power to lease any portion of open proclaimed land. Notice and calls for application for grant of a lease are made. The conditions of the lease are laid down in the law which provides that the necessary capital must be available, that the mining shall be properly done, and that rent and royalties must be paid (ibid., sec. 1 to 11). No royalties are paid on gold, except on leased land. Royalties, however, are paid on base metals. (Ibid., sec. 121.)

On discovering base metals and convincing the mining examiner that they exist in payable quantities, a prospector is entitled to peg 100 claims on either crown or public land free of license money, and also a digger on proclaimed ground of any sort is entitled to 100 base metal claims, as contracted with the allowance of 50 claims for precious metals. The claim fee in the case of base metals is very low, being 1 penny per month per claim for the first year and 6 pence per month per claim for any other succeeding year.

With respect to precious stones, any white male inhabitant over 18 years of age is entitled to take out a license to prospect for precious stones on State land. The license may be renewed indefinitely, and the prospector has the right to explore a "prospecting area" for one month (The Precious Stones Ordinance, 1903, with amendments, sec. 4). On private land the owner may prospect without a license but must give notice of his intention to the District Registrar. The prospector may

prospect with the consent of the owner (ibid., sec. 7). Discoveries must be reported to the District Registrar (ibid., sec. 8). The discoverer of alluvial diamonds, whether on Government or private land, is entitled to select 50 claims in one block; following the discoverer, the owner is entitled to select the next 200 claims (ibid., sec. 41 and 42). The Precious Stones Act of 1927 has set up a restriction on the quantity of output of alluvial diamonds. The Government has been revested with the mineral rights of several hundred farms in the Cape Province which are owned under freehold. The Government contends that the success and stability of the diamond industry are dependent upon monopoly. The Minister of Mines determines the maximum quantity and value of precious stones which may be recovered from the alluvial fields. When this determined quantity has been exceeded or is likely to be exceeded, he may, by proclamation, (a) forbid the issuing of further digger's certificates, (b) stop the issuing of claim licenses, (c) declare that no further land be proclaimed as alluvial digging, and (d) prohibit prospecting either on Government or private land; (e) restrict the output; (f) prohibit the subdividing of parceled land in proclaimed or about to be proclaimed area in order to multiply the number of owners' claims, and (g) prohibit the combination of two or any number of claims under one management. It should be observed that this is a national law and applies to all provinces. The Minister of Mines is given the power to declare that no claim holder may employ more than 20 natives in working an alluvial claim.

Orange Free State

Precious Stones:- The right to prospect is confined to white persons over the age of 15 years (Mining of Precious Stones Ordinance, 1904, sec. 11 (2)). The landowner may prospect without license if he gives notice of his intention to the Resident Magistrate (ibid., sec. 11), but as soon as he prospects or grants permission to others to prospect, the Government may proclaim his land as an alluvial digging, mine, or prospecting area (ibid., secs. 1 and 2). The Lieutenant-Governor has the power to grant a license to prospect on State land for precious stones. The discovery of precious stones must be reported (ibid., sec. 14). If discovery is made on State land, the discoverer is entitled to not more than an undivided half share in the mine if proclaimed (ibid., sec. 15) and the owner to an undivided one-fifth. In the event of discovery by the owner, he is entitled to six-tenths. The State owns the remainder in either case.

After an alluvial digging has been proclaimed and the discoverer and owner have taken their claims, the remainder is available for pegging by license. Any white person over the age of 18 is entitled to a license by the payment of a monthly fee (ibid., secs. 69, 70, and 76).

The State has no proprietory right in the proclaimed existing mines (e.g. Jagersfontein and Koffyfontein), nor of the unproclaimed existing mines (e.g. Lace, Orange Free State, New Briekopjes, Monastery, and Estate diamond); however, they must pay the State a monthly rent or tax on each claim (ibid., secs. 60 and 61.)

Precious Metals:- The owner of private land may, by giving notice of his intention, prospect without license; but if he prospects or permits others to prospect, his land may be proclaimed as a public digging (Mining of Precious Metals Ordinance, 1904, secs. 1, 2, and 3). A prospecting license is required of all others. A license is granted to any white person and is kept in force by payment of a monthly fee (ibid., secs. 18 and 19). The Lieutenant-Governor has the power to grant the right to prospect on State land to any company or person on such terms as he may deem fit (ibid., sec. 22). Upon the discovery of precious metals in payable quantities on private or State lands, the Lieutenant-Governor has the power to proclaim such land as a public digging (ibid., sec. 30). Both the owner and discoverer have prior rights in pegging claims. The discoverer of an alluvial field on State land holds his claim free of license money (ibid., sec. 46). The owner of land on which an alluvial field has been discovered is free of license fees if the minerals have not been reserved to the State (ibid., sec. 47). A license to peg out claims on a public digging may be issued to any person of European descent and over the age of 18 years by payment of license fee (ibid., sec. 54). Where ore is crushed by machinery, the monthly license fee is greater than where machinery is not used (ibid., sec. 61). Claims may be transferred (ibid., sec. 84). If claims are not properly worked, the claim is forfeited. (Ibid., Secs. 88 and 89).

Base Metals:- Any white person with the consent of the owner of private land may prospect for base minerals, including petroleum, by obtaining a prospecting license (fees due monthly) from the Resident Magistrate. The owner requires no license (Mining of Base Metals Ordinance, 1904, Sections 1, 2, and 3). Discovery must be reported (ibid., sec. 8). On State lands, prospecting is permitted under conditions laid down in the license by the Lieutenant-Governor (ibid., sec. 5). The minimum royalty is fixed .

Cape of Good Hope (including Bechuanaland)

Precious Metals:- No person other than an owner may prospect for precious metals without taking out a license (Precious Minerals Acts, No. 31 or 1898, and No. 45 of 1905, sec. 59), but the only requirement of an applicant for a license to prospect on State or private land is that he be a person of legal age and of good character (ibid., sec. 4). The license is in force one year (9b9d., sec. 5). The holder of a license has the right to peg out an exclusive prospecting area on all unoccupied State land (ibid., sec. 7) and, with the owner's permission, to prospect on private land (ibid., sec. 6). The prospector must report the discovery of any minerals to the Government (ibid., sec. 12). The prospector who makes a discovery of precious minerals in payable quantities on either reef or alluvial diggings is entitled (on proclamation) to peg out a larger number of claims (ibid., sec. 14 to 16, and 78 to 81). The owner of the land in a reef digging is entitled to a large number of claims or a lease (ibid., sec. 64), and if on alluvial diggings to a large number of claims (ibid., sec. 107). If the digging is proclaimed, the owner is entitled to three-fourths of the license money collected by the Government on his land, and if leased, to one-half the rents and royalties (ibid., secs. 63 and 106). Failure to work a claim leads to an increase in license fees (ibid., sec. 48) and in 12 weeks to a proclamation of abandonment (ibid., sec. 54). All holders of claims pay license fees or rent and royalties. The Governor has the authority to grant leases on any abandoned diggings. (Ibid., sec. 55 and 99).

Base Minerals:- The prospector who proves that he has found workable quantities of base minerals on State land is entitled to a lease for one year with the right of further renewal. The rent is prescribed. There is no law dealing with base metals on private property the title of which contains a reservation of minerals in favor of the State.

Precious Stones:- No person other than an owner may prospect without taking out a license. A license entitles the holder to prospect on all unoccupied Government land open to prospecting throughout the Province and to peg out a prospecting area over which he has the exclusive right to prospect so long as his license is in force. The holder of a prospecting license may also propsect on private land with the consent of the owner and subject to such terms and conditions as he may impose. In the event of a discovery he is bound to notify the Government.

A prospector who proves to the satisfaction of the Civil Commissioner that he has discovered precious stones in payable quantities in a new mine on Government land is entitled to an undivided half share in such mine on its being proclaimed. If the discovery is on private land the discoverer is entitled to an undivided one-fourth share and the owner to a similar share in the mine. The discoverer and the owner of the land become joint and not several proprietors of the shares of the mine to which they are entitled. Should neither the discoverer nor owner wish to work the mine, the Governor-General may call for tenders for the working of it, subject to such conditions as may be agreed upon between the Governor-General and the parties holding shares in the mine.

A prospector who proves to the satisfaction of the Civil Commissioner that he has found precious stones in payable quantities, receives a certificate entitling him, prior to the allotment of any other claims in the digging, to peg off 20 claims free of license money upon the proclamation of the ground where the discovery was made as an alluvial digging. If an alluvial digging is proclaimed on private land the owner is entitled, after the prospector has selected his claims, to peg off 50 claims and hold them free of license charges. If such owner is also the discoverer he is entitled to the discoverer's claims as well. After the discoverer and owner have selected their claims any certificated miner may peg off one claim on the area proclaimed, if available, and after a lapse of seven days may peg off a further five claims. The license fee for a claim is 5 shillings per month. In order to become a certificated miner a person has to satisfy the authorities that he is a fit and proper person to be registered as a claimholder and is of good character. The owner of land which is proclaimed an alluvial diamond digging is entitled to receive from the public revenue as compensation for any surface damage he may sustain, half of the license moneys, rents, and royalties collected in respect of such digging.

The law provides for the granting of leases for the purpose of dredging and sluicing in any public river of which the bed is not vested in any private individual, and in respect of which ordinary alluvial mining acn not be carried on. Such leases are granted for periods of three years, renewable from time to time, and the area leased must not exceed 4 miles in length. The rent charged is 5 pounds per mile per annum for the first year, and a royalty of 1 pound per cent on the amount realized by the sale of the precious stones won during the second and succeeding years.

Tanganyika

Under the conditions of a treaty between the United States and Great Britain (Feb. 10, 1925) nationals of the United States are on the same footing as British nationals in being ensured of freedom of navigation and complete economic, commercial, and industrial equality in Nyasaland. Concessions for the development of the natural resources of the territory shall be granted on the same basis, and no concession having the character of a general monopoly shall be granted.

Tanganyika (Protectorate)

Before any person may prospect for gold, precious stones, or minerals, he must obtain a prospecting license (The Mining Ordinance, 1920, secs. 3 and 4). Any person not under the age of 21 years may obtain a prospecting license, whether a British subject or not, and whether a European or not (ibid., sec. 8 (1)). Except on land excluded from prospecting (ibid., sec. 9), the prospector may search, peg out, and occupy a claim (ibid., sec. 10), which must be registered. Although a license will not be granted to a partnership or corporation, it will be issued to an individual as agent (The Mining Regulations, 1921, amendment, 1922, sec. 4A). The holder of a prospecting license may apply for authority to prospect on any land excluded from prospecting and occupation, and the Governor may grant such authority on such terms as to area, duration, rent, and conditions as he thinks fit (The Mining Ordinance, 1920, sec. 12 (a)). On discovery, the holder of the authority may be called upon to apply for a lease (ibid., sec. 12 (b)). The discovery of payable gold, precious stones, or minerals must be reported (ibid., sec. 34). No mineral produced in prospecting may be sold (ibid., sec. 21). A lease is necessary to mine for sale.

The right to all minerals is vested in the Governor, who may grant leases (ibid., sec. 22). While the law prescribes certain limits, within those limits the Governor fixes the area, rent, royalty, and labor conditions (ibid., sec. 25, 26 and 27). The lease may not exceed 20 years, but is renewable (ibid., sec. 29). If special conditions make it necessary, the Governor may change the conditions of a lease in order to make it workable (ibid., sec. 37).

According to The Oil Mining Ordinance, 1922, the Governor may, if he thinks fit, grant licenses to prospect, or leases to win, mineral oils to such persons, over such areas, and on such conditions as he may deem expedient (ibid., sec. 4). The Governor may, if he thinks fit, make regulations in connection with the mineral oil mining industry. (Ibid., sec. 5).

Zanzibar

A license is required for prospecting (The Minerals Decree, 1925, sec. 3). The British Resident may issue a license to prospect on public land to any male person over the age of 21 years subject to such conditions as he may see fit; save as may be expressly stated in the license, the licensee shall have no right or interest in any minerals which he may discover in the course of prospecting under such license (ibid., sec. 4). The owner of land is also required to have a

license (ibid., sec. 5). The discovery of minerals must be reported (ibid., sec. 7). The British Resident may specially authorize any person to prospect on any land in the Protectorate (ibid., sec. 8), and he may issue a mining license to any person (ibid., sec. 9). In the event of the discovery of any mineral on public land, the British Resident may take such measures as he may think fit for developing the same; may sell, lease, or otherwise dispose of such mineral; and may award the discoverer with remuneration or privileges. (Ibid., sec. 11).

Kenya

Prospecting and mining on State land are permitted by virtue of (a) prospecting license, (b) sold exploration license, (c) protection area, (d) registered claim, or (e) mining lease or coal lease. (The Mining Ordinance, 1925, sec. 18). To have an interest in any one of these, a person must not be under 16 years of age (ibid., sec. 96). A prospecting license, good for a year, authorizes prospecting for minerals other than oil, to peg claims, and acquire protection areas (ibid., sec. 17, 19 and 23). The protection area is the area (the size is defined) marked off by the prospector, in which he has the exclusive right to prospect. (Ibid., sec. 30).

Where especially large areas are required for large-scale prospecting, application is made for a sole exploration license. The grant of such a license, which is in the nature of a concession, is a matter within the discretion of the Governor, who considers the public importance or imperial utility of the proposed operation (ibid., secs. 25 - 29).

The license holder obtains the right to developmental work by pegging out and registering a claim; any number of claims may be held by the same person (ibid., secs. 36 and 47). The dimensions are established by law (ibid., sec. 34). The minimum work to be done on a claim is also prescribed (ibid., sec. 44). No mineral may be disposed of (ibid., sec. 46) without a lease for which the claim holder has certain preferential rights (ibid., sec. 38).

Mining leases for which the maximum area is defined (except for coal which is at the Governor's discretion) are for a term of 10 years, with a proviso for renewal (ibid., secs. 49 - 52). The rent, royalties, and labor conditions are defined in the law. (Ibid., secs. 53 - 55).

If the prospector enters private land to prospect or peg out a claim, he may be required to deposit fees or enter into a bond to compensate the owner for losses or damages, (ibid., secs. 60 - 62), and no lease will be granted until the Government is satisfied that compensation has been paid by the applicant to the landowner (ibid., sec. 63 (1)). No claim for common minerals may be pegged without the consent of the owner of the land. (Ibid., sec. 63 (2)).

Concerning Petroleum:- The Governor-in-Council may make regulations to provide for the granting of licenses or leases to prospect and mine for oil and for the effective control of any rights granted. (Oil Production, Ordinance, 1924, sec. 7). All licenses and leases shall be granted only on implied agreement by the licensee and lessee with the following: (a) That His Majesty's Government shall

have the right of pre-emption at current commercial prices of all crude oil won from the area concerned and of all products of refining or treatment of such oil; (b) that in the event of war, whether His Majesty's Government is involved or not, the Governor, on behalf of His Majesty, shall have power to take control of the works and plant in the area granted or to take control of any refinery or stores of Oil; (c) that the Governor shall have the power to regulate the site of any refinery or place of storage of oil in the colony and Protectorate of Kenya (ibid., sec. 8). An exploration license shall be for such term and subject to such conditions as the Governor may direct, and shall be for a maximum term of one year. It may be renewed (ibid., sec. 5). It confers upon the licensee the preferential right to apply for an oil prospecting license (ibid., sec. 9). The Commissioner of Mines may, with the approval of the Governor, grant oil prospecting licenses for not more than three years (ibid., secs. 14 and 21). The oil prospecting license confers the sole right of prospecting for oil (ibid., sec. 17). The holder of the license is permitted to remove and use 100 tons of oil for further prospecting or mining (ibid., sec. 19). He may sell or export the oil from the area by permission of the Governor subject to the payment of royalties (ibid., sec. 20). The Governor may grant oil leases to the holders of oil prospecting licenses (ibid., sec. 24). The period of the lease is 21 years, subject to renewal for further periods of 10 years (ibid., sec. 28). Lease is subject to rent and royalty (ibid., sec. 31). No person may erect an oil refinery in the colony and Protectorate of Kenya without the sanction of the Governor. (Ibid., sec. 32.)

Nyasaland

A license is required for prospecting. This may be obtained from the Director of Mines at his discretion. The license is good for six months and may be renewed. (The Mining Ordinance, 1906, sec. 7). The holder of a prospecting permit may mark off a prospecting area (ibid., sec. 8). If he wishes to prospect on private land, he must enter a bond to assure the owner against damages (ibid., sec. 11). The discovery of precious stones or precious metals must be reported (ibid., sec. 12). The original discoverer (one who has proved that his discovery of precious stones or precious metals is more than five miles from any previous discovery) is entitled to 16 reward claims free of license fees. The successful prospector (a holder of a prospecting area within a field proclaimed as public) is entitled to four claims. The owner is entitled to eight claims (ibid., secs. 18, 19 and 20). A Miner's Right may be issued by the Director of Mines, authorizing the holder to take up one claim (only two Miner's Rights are issued per person).

In the event that the Governor decides not to declare a locality a public field, he may grant the prospector a lease for a maximum period of 21 years on such terms as he may see fit. (The rent not to exceed 1 pound per acre nor be less than 1 shilling). Should the land be private, the owner gets one-half the rent (ibid., secs. 24 and 25). All minerals and precious tones either are or may be subject to royalties (ibid., sec. 28). All forms of mining interests may be transferred or assigned (ibid., sec. 27). The lessee must begin to mine within six months, must employ a certain number of men, and must mine more or less continuously (Rules Governing Mining Leases (July 1911), sec. 11). However, the Mining Rules (No. 92 of 1911, sec. 2) state that every prospecting area and claim must be worked by at least one European and two natives during at least seven days out of every calendar month.

No license or lease shall be granted to any firm, syndicate, or company which shall not at all times be and remain a British company, registered in Great Britain or in a British Colony or Protectorate, and having its principal place of business within His Majesty's Dominions; the Chairman of the company and all the remaining directors shall at all times be British subjects, and the company shall not at any time be or become a corporation directly or indirectly controlled by foreign corporations. (The Mining Regulation (Oil) Ordinance, 1910, No. 5 of 1910, sec. 13).

The Gold Coast, Ashanti, and Sierra Leone

The mining laws relating to the Gold Coast Colony, Ashanti, and the Northern Territories are divisible into two parts; those relating to the Gold Coast and the Ashanti on the one hand, and those relating to the Northern Territories on the other. As regards the Gold Coast and the Ashanti, operations are carried on under what may be described as the Concession System. The right to mine for minerals is based, in the main, upon the grant or a concession from the native or natives having rights over the land, or lands, to which the concessions relate. The Government does not claim any prerogative right to minerals, but controls prospecting and mining, and (in the Gold Coast only) helps operations by means of a system of licenses. In the Northern Territories, on the other hand, the right to mine or prospect for minerals is based primarily upon the grant of a State license or option, but arrangements with the natives may, and generally will, also be necessary, if the State license or option overrides individual rights. In the case of mineral oil concessions, the concessioner must be British, whether such concessioner be a person, firm, syndicate, or company (Concessions Ordinance, 1900 (Gold Cost) sec. 21). Every concession in respect to mineral law is subject to the approval of the Governor. (Ibid. sec. 21 (3)).

Prospecting may be commenced before any concession has been obtained, but before commencing prospecting operations, a prospecting license must be obtained from the Governor (unless the person prospecting is prospecting in an area in relation to which he holds a mining license) (ibid., sec. 2, and sec. 27 (1)). The license gives no right to obtain minerals got; it is not an exclusive license, it is a bare license, and as such, presumably revocable.

Royalties in the form of duties in respect to profits, are payable to the Government by all concession holders. Until recently no export duties were levied on minerals or precious stones, but by the Diamond Export Duty Ordinance, 1919, an export duty of 5 per cent of the value of diamonds exported from the Colony is imposed. By the Mineral Oil Preemption Ordinance, 1907, the Government is given a right of preemption over all crude oil raised or gotten in the Colony, and of all products of the refining or treatment of such oil.

The law relating to prospecting and mining in the Northern Territories of the Gold Coast is entirely different from that in existence in the Gold Coast and Ashanti. The Concession System does not apply, and prospecting and mining operations must be carried out in virtue in a series of licenses (some of which are termed options) granted by the Government authorities, which licenses confer upon the licensees, subject to various important conditions and reservations, the right to prospect or mine for minerals. (The Mineral Rights Ordinance, 1904 (Northern Territories) secs. 1 to 37).

Application for recommendation for a prospecting license is made to the Governor of the Gold Coast (ibid., sec. 5). Application for a prospecting option, mining option, or mining license is made to the Chief Commissioner (ibid., secs., 15, 24, and 33), and for a dredging license to the Governor (Northern Territories, River Ordinance, 1903, Section 5). The Governor may or may not recommend the grant of a prospecting license as he (in his discretion) thinks fit.

The prospecting license continues in force for six months and may be renewed for a like period (ibid., sec. 11). A prospecting option continues in force for three years (ibid., sec. 12 (2)). The holder of a prospecting option will on application be granted as many mining options in the prescribed form as he requires, over as many blocks of land, not exceeding five square miles, or as have been defined in the application, subject to the prescribed conditions and to any conditions with regard to dealing with native chiefs or any native person as the Chief Commissioner may think fit to impose (ibid., sec. 26). The holder of a mining option on application will be granted a mining license if such Chief Commissioner is satisfied that he is in a position to commence actual mining operations (ibid., sec. 34). If the application is refused, the mining option may be extended as long as five years. The mining license may be for any time not exceeding 90 years. (Ibid., sec. 36 (1)).

It is necessary to secure a license from the Comptroller of Customs in order to carry on the business of winning, extracting, smelting, dressing, defining, or dealing by way of wholesale in metals or metallic ores. (The Nonferrous Metals Industry Ordinance, 1919, sec. 3, (1)).

The Government has the right of preemption of all crude oil raised, won, or given in the Colony, and of all products of the refining or treatment of such oil. (The Mineral Oil Preemption Ordinance, 1907, Section 23).

In order to export diamonds from the Colony, it is necessary to register such diamonds for export through the Government agents in London. Diamond exports are dutiable. (The Diamond Export Duty Ordinance, 1919, secs. 3, 4, and 5).

The mining law relating to the Colony and Protectorate of Sierra Leone is similar to that in operation in Ashanti. That is to say, the right to mine for minerals is based in the main upon a grant, or concession, from the native or natives having right over land to which the concession or concessions relate. It should be observed, however, that by the unoccupied lands ordinance (Ascertainment of Title Ordinance, 1911), the Government was given power to acquire unoccupied lands, as defined in that ordinance in the manner therein provided. All lands being so acquired, title thereto becomes vested in the State, and the Government may grant such lands, or parts thereof, to private persons. All Government grants under the above mentioned ordinance, are deemed to contain an express reservation to the Government of all mines, metals, minerals, precious stones, and mineral oils, and of a right on the part of the Government to enter on lands conveyed by such grant for mining purposes. (Occupied Lands Ascertainment of Title Ordinance, 1911, sec. 8).

The following steps should be taken by a person desiring to obtain a valid concession: (1) Obtain a license to prospect, (2) obtain from the proper persons a concession in writing, (3) secure and register such a document in the Office of the Registrar General, (4) question natives of such a concession, (5) take steps to obtain the provisional recommendation of the Governor, and (6) take the necessary steps to obtain a certificate of validity.

Nigeria

The entire property in the control of all minerals and mineral oils in, under, or upon the lands in Nigeria is vested in the Government. (The Mineral Ordinance, 1916, sec. 3 (1)).

There is no discrimination against aliens, but a license is required to prospect (ibid., secs. 8 and 9) which is normally good for one year. (Ibid., sec. 9 (3)).

Any person who has, by himself or by a person in his employ, prospected the area over which the license is applied for, may be granted, on application, an exclusive prospecting license (ibid., sec. 11 (1)). If required by the officer to whom application is made, the applicant must produce evidence to satisfy the officer that he possesses or commands sufficient money to enable him to discharge all expenses and payments which may be incurred by him in the course of prospecting. (Ibid., sec. 6 (2)).

Before mining may be commenced, it is necessary to obtain either a mining right or a mining lease, or the Governor's permission to mine; the term of the grant may not exceed 21 years (ibid., secs. 19 to 28, inclusive). Wherever a lease or license is granted under the Mineral Oil Ordinance, 1914, in respect of any lands included in the area of a mining lease, prospecting lease, or mining right, the rights of the holder of a mineral-oil license has preference (ibid., sec. 55 (1)). It is intended that any mineral oil on or under land included within the area of a mining lease shall be worked by the Government (ibid., sec. 55 (2)). The lessee is obliged to pay royalties (General Minerals Regulations, 1916, Section 3) and surface mineral rents (ibid., sec. 21 (2)). He must commence mining operations within six months (ibid., sec. 31 (1)) and keep continuously employed at it. (Ibid., sec. 31 (2)).

No alien shall acquire any interest or right in or over any lands from a native except under an instrument which has received the approval in writing of the Governor. (Native Land Acquisition Ordinance, 1917, sec. 3 (a)).

The Governor may grant a lease but may not sell Government land without the approval of the Colonial Secretary. (Crown Lands Ordinance, 1918, secs. 3 and

4). A lease does not confer the right to any mineral or mineral oil - that is, the Government excepts the right to enter such lands. (Ibid., sec. 21).

A license or lease is necessary to work or drill for mineral oils (The Mineral Oils Ordinance, 1914, sec. 3) and no lease or license shall be granted except to a British subject or to a British Company registered in Great Britain or in a British Colony, and having its principal place of business within His Majesty's Dominions; the chairman of the board of directors, the managing director, if any, and the majority of the other directors must be British subjects. (Ibid., sec. 6 (2)).

In the event that tin ore or metallic tin is exported for smelting in any place outside of the United Kingdom or a British possession, an export duty equal to 50 per cent of the maximum royalty ($7\frac{1}{2}$ per cent) is assessed. (General Mines Regulations, 1916, sec. 3 and 4).

Uganda

No one is permitted to prospect or search for minerals in Uganda without a prospecting license. Such a license may be issued to any person ("person" includes any body of persons, corporate or unincorporate) of European birth or descent (General Mining Rules, 1902, sec. 1) upon personal application, and it is in force as long as the fee is paid (The Uganda Mining Regulations, 1902, sec. 6). The prospector is required to enter a bond for repair or damages done in prospecting on private land (ibid., sec. 8). The holder of a prospecting license may stake out an exclusive prospecting area (ibid., sec. 10). Should he make a discovery he must declare it to the Government (ibid., sec. 11). When the Government is satisfied of the existence of gold or silver ores or precious stones in payable quantities it may proclaim a mining centre or public field (ibid., secs. 15 and 16) Then the holder of the prospecting license is entitled to abandon his prospecting area and take up prospecting claims of such number and size as prescribed in the law. The prospecting claim certificate gives him the right to mine (ibid., sec. 17). The owner may take out one claim for each 100 acres (ibid., sec. 32). To mine on a declared public field a digger's license only is required (ibid., sec. 20). Any person has the right to take out two diggers' licenses on each public field (ibid., sec. 21). Claims may be transferred (ibid., sec. 23). The by-laws for the field are made by a committee of diggers (ibid., sec. 25). The owner of any private land included in any public field receives one-half of the fees paid in respect to such land. (Ibid. sec. 20).

If the minerals in the land have been reserved to the owner he has the right, upon giving notice to the Government, to prospect without a license (ibid., sec. 30); but he, too, must declare discoveries. (Ibid., sec. 311).

Any land not specially exempted may be leased by any licensed person (General Mining Rules, 1902, sec. 15) for any term not exceeding 21 years, recoverable for the same period. (Uganda Mining Regulations, 1902, sec. 45). No royalties, though subject to alteration, are designated for gold, silver, precious stones and coal; all other royalties are fixed by the Commissioner of Mines (ibid., sec. 42). One-half of the rent received by the Government for mining and one-half the royalties, in so far as they do not exceed the rent payable on leases granted on private land, are paid to the owner. (Ibid., sec. 43).

Southern Rhodesia

The right of searching and mining for and disposing of all minerals (including mineral oil) is vested in the British South Africa Co. All grants made by the British South Africa Co. prior to May, 1904, have been confirmed. (Mines and Minerals Ordinance, 1903, Sec. 3). (ibid., sec. 6). However, rights can be acquired to all minerals except precious stones and building stone. (Ibid., sec. 4)

Any person of full age, company or syndicate, when duly authorized by the Administrator may take out a prospecting license (ibid., sec. 9). If the applicant is an unregistered company or syndicate the full name of all the members, of whom there may not be more than six, must be given.

The prospector's license entitles him to peg off: (1) One block of 10 gold reef claims; (2) one block of 30 base metal claims; (3) one alluvial claim (other than diamond or precious stones (ibid., sec. 11); (4) one coal location; and (5) one mineral oil or natural gas location (ibid., secs. 31 and 105).

Any holder of a prospecting license who discovers an ore-bearing vein ("reef") or an ancient working must post a notice (ibid., sec. 13) and establish the position of his discovery by a peg marked "D. P." This confers the exclusive privilege of prospecting within a radius of 1,000 feet for 31 days with extension of 90 days if a vein is found (ibid., sec. 14). Any time after placing the D. P. peg before the end of the exclusive period the prospector must peg off a block and post registration notices. (Ibid., secs. 15 and 18).

The holder of a registered block of claims has not only the right to mine everything within his block, but also the extralateral right of pursuit of such portions of his discovered vein as descend outside the limits of the vertical block. (Ibid., sec. 22).

Within six months from the date of registration of the block the claimholder must execute at least 30 feet of development work on his block, a further 30 feet within the next six months, and each succeeding year he must execute 60 feet of development (ibid., sec. 24). An inspection certificate, which is absolutely necessary to hold the claim, can not be obtained without the accomplishment of work. (Ibid., secs. 24, 25, and 26).

All registered mining locations (registered prior to 1908) are held in joint account with the British South Africa Co. in the proportion of seven-tenths by the registered holder and three-tenths by the British South Africa Co. (ibid., sec. 40). However, the holder of any claim registered since Jan. 1, 1908, pays royalties on gold on a sliding scale (Mines and Minerals Ordinance, Amendment Ordinance, 1907, secs. 11 and 12) varying from 2 1/2 per cent to 7 1/2 per cent (ibid., sec. 13) while all other minerals require the payment of a 2 or 3 per cent royalty (ibid., secs. 18 and 19), depending upon the mineral.

A claimholder may secure the authority to mill his gold ore. He, however, is not permitted to work more than 10 claims, nor to operate more than five stamps (or equivalent), nor to crush more than 750 tons a month. (Mines and Minerals Ordinance, 1903, sec. 44).

Where a mining location is situated on private land, the owner is entitled to one-half of the claim licenses that accrue to the British South Africa Co. (Ibid., sec. 49).

Mining at a depth of less than 250 feet is prohibited under reserved lands (towns, roads, playgrounds, etc.). (Ibid., secs. 88 - 91).

Any holder of a mining location may obtain a Special Registration Certificate which confers upon the holder an indefeasible title to all surface and mining rights. (Ibid., secs. 57 and 58).

The discoverer of indications of coal may obtain a coal prospecting area not exceeding 150 morgens in extent which must be beaconed (ibid., secs. 100 - 102). Then by filing a declaration that beacons have been erected, the prospector has the exclusive right to prospect for one year (ibid., secs. 103 and 104). Upon the discovery of coal the holder has the right to peg off a coal location, the extent of which depends upon the amount spent in prospecting. (Ibid., secs. 105 - 108).

The selection of coal location protects the prospector until he gets the full protection of certificate or registration (ibid., secs. 109 - 110). The royalty payable is determined by the amount of merchantable coal raised (ibid., sec. III). No extralateral rights exist for coal. (Ibid., sec. 114).

The holder of a prospecting license may peg off a mining location for copper, bismuth, cobalt, mercury, molybdenum, nickel, thorium and allied substances, tin, tungsten, scheelite, uranium, vanadium, mineral oils, natural gas, salts, aluminum* and its compounds*, asbestos*, antimony*, barium*, strontium*, chrome*, graphite*, gypsum*, magnesite*, manganese*, mica*, zinc*, iron*, lead*. (Mines and Minerals Ordinance Amendment Ordinance, 1907, sec. 17, and Mines and Minerals Ordinance, 1903, sec. 117). Upon this location he has the exclusive right to prospect for a period of 31 days within an area with a radius of 3,000 feet from the discovery point (ibid., secs. 118 and 119). Pegging out a location requires registration. The location must not exceed 30 reef (vein) claims of 90,000 square feet each (ibid., sec. 118). No extralateral rights exist for these minerals. As soon as working at a profit begins, a monthly payment of 5 pounds must be made to the British South Africa Co. if the registration antedates 1908, otherwise a royalty of 2 per cent on the gross value is paid on those minerals marked with an asterisk in the foregoing list and 3 per cent on those not so marked. (Ibid., sec. 125; and Mines and Minerals Ordinance Amendment Ordinance, 1907, sec. 18).

Mineral Oils and Natural Gas:- The holder of a prospecting license may prospect for mineral oils or natural gas upon any land open to prospecting. He must post prospecting notice of his intention. This gives him the right of prospecting over an area with a radius of 1 mile. After 31 days the Secretary of Mines reserves for him an area of 1 square mile upon which he has exclusive prospecting rights for six months. This period may be extended upon proof of bona fide operation. In the discovery of oil or gas the prospector has the right to peg off six

contiguous blocks of claims of the same size as claims for copper and under obligations similar to those pertaining to copper. (Mining Law Amendment Ordinance, 1914, No. 20, 1914, sec. 45).

A permit from the British South Africa Co. is necessary to prospect or dig for precious stones in alluvial deposits. (Precious Stones Mining and Trade Ordinance, 1906, No. 17, 1906, sec. 6). The digger must register his claim within 31 days and pay a monthly rental (ibid., sec. 7). If necessary, private land may be expropriated. (Ibid., sec. 12).

In 1892 the British South Africa Co. granted to the De Beers Consolidated Mines, Ltd. the exclusive license to work all the diamondiferous ground of the company. On payment of £25,000 compensation to the discoverer, the De Beers Consolidated Mines has the right to expropriate any "pipe" discovered.

Significant statement upon the effect of the law:- "The efforts of the individual prospector have in recent years not resulted in discoveries of any importance, and, unless some other means of prospecting can be encouraged, gradual diminution of prospecting is inevitable. It is therefore to be hoped, in the interest of the country, that some system may be devised at an early date, under which companies or individuals, who are prepared to incur considerable capital expenditure in intensive and scientific prospecting, can be protected during the prospecting stage with the assurance that if their operations lead to the discovery of valuable minerals they will be able to acquire mining rights in these minerals." C. D. Fleming, Acting Sec'y, Department of Mines and Public Works, Report of Mines for the year 1926, p. 2, Salisbury, Rhodesia, 1927.

Northern Rhodesia

In principle the mining laws of Northern Rhodesia are similar to those of Southern Rhodesia. The right to search and mine for all minerals and mineral oils is vested in the British South Africa Co. (The Mining Proclamation, 1912, Preamble).

To prospect, a license is required, and it must be registered with the Government (ibid., sec. 6). The registered prospecting license gives the right to prospect for such minerals as specified upon any land of the British South Africa Co. open to prospecting and upon any private land outside the location on payment to the owner at a rate fixed by tariff (ibid., sec. 7 (2)). Upon discovery, the prospector posts a discovery notice which gives him the exclusive rights for 31 days, and if a vein is discovered within that period he is allowed 90 days thereafter. For precious metals the prospecting area is described by a radius of 1,000 feet from the discovery point; for base metals the area is 3,000 feet. (The Mining (Amendment) Proclamation, 1915, sec. 3).

The prospector should peg out his mining location and register it within the 31 days granted by his license, but may in the discretion of the Administrator be allowed up to 93 days. (Ibid., sec. 4).

The size of a mining location varies according to the nature of the occurrence. For precious metals in a reef deposit, it is a block of 10 contiguous claims, each 100 by 600 feet; for alluvial deposits of precious metals it is 200 feet square; for base metals it comprises 30 contiguous claims, each of 90,000 square feet; for coal 100 to 300 acres may be taken on the basis of 1 acre for every £1 expended in prospecting.

Coal:- The holder of a prospecting license is authorized to apply for a "coal prospecting area" not exceeding 300 acres (The Mining Proclamation, 1912, sec. 19 (1)). A "coal certificate" issued by the Government gives exclusive prospecting rights for one year (ibid., sec 19 (2)). Upon the actual discovery of coal the prospector may peg off a definite coal location - not to exceed 300 acres - which when properly beaconed may be registered (ibid., secs. 19 and 16). Failure to register within six months after the selection of the location results in forfeiture. (Ibid., secs. 19 and 7).

The holder of a mining location must execute at least 30 feet of development work within four months, and at least 60 feet a year afterwards, except in the case of alluvial and coal locations, for which he must obtain inspection certificates. Extra development work done on one mining location may be regarded as having been done on any other mining location under the same ownership.

The holder of a registered mining location who has obtained all inspection certificates necessary and has paid all rents and royalties due, may apply for a Special Registration Certificate (ibid., sec. 27). This certificate confers upon its holder an indefeasible title to all the surface and mining rights appertaining to such locations. (Ibid., sec. 28).

The British South Africa Co. reserves the right to subscribe one-third of the working capital at par, or upon such terms as may be given to other subscribers; or it may commute its one-third share upon a basis of 33 1/3 per cent of the balance of the total under interest remaining after the cost of all bona fide development work has been deducted.

South West Africa

South West Africa is a "C" mandate exercised on behalf of the Union of South Africa. Mining is regulated generally by the German Imperial Mining Ordinance, 1905, as amended by Proclamation No. 24 of 1919. There is no legislative of administrative discrimination against nationals of the United States. Indeed, it is the intention of the ordinance that, subject to certain reasonable and necessary restrictions in the interest of the public and private landowners, the whole country shall be freely open to prospecting and mining. This idea has been furthered by the cancellation, in 1920, of all then existing mining concessions (Concessions Proclamation and Mining Law Amendment Proclamation, 1920), except the diamondiferous area which had been given out by the German Administration; this remains closed to prospecting.

Prospecting is permitted to any white person of the ages of 18 years or upwards who is in possession of a prospecting license. The prospector may peg out a claim, and on so doing must notify the mining authority. Mining can not be carried on until the prospecting claim is converted into a mining area, but this can be done even without previous discovery. This conversion must be recorded and the record bestows upon the holder the exclusive right to mine for precious and base metals. The size of a precious metals claim is about 20 acres and of a base metals claim about 180 acres.

The mining law in force in the territory is the Imperial Mining Ordinance, 1905 (German), as amended by proclamations No. 24 of 1919, No. 12 of 1920, No. 59 of 1920, No. 29 of 1921, No. 11 of 1923, No. 15 of 1925, and No. 10 of 1926.

Mining must be commenced within two years and must be continued without interruption. There is both a claim tax and output royalty, and in certain parts of the territory certain specified sums of money must be expended as a proof of the occupation of a certain number of men. The landowner receives one-quarter of the output royalty. The prospector or miner is required to compensate the owner for damages to and interrupted use of the land.

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Return to D. Harrington

Circular 6107 March, 1929

Department of Commerce

United States Bureau of Mines
Scott Turner, Director

INFORMATION CIRCULAR

MINING PRACTICE AT MORENCI BRANCH, PHELPS DODGE CORPORATION, MORENCI, ARIZ.

BY McHenry Mosier and Gerald Sherman

CONSULTING ENGINEERS

Washington, D. C.
March, 1929.

This paper is the first of a series of publications dealing with the caving method of mining and is to be followed by similar papers on other mines in Arizona and in other districts throughout the United States, where this system is used.

At the same time that these reports are being prepared for publication, and there will be a dozen or more, material is being collected for a general bulletin presenting the caving system of mining, its application and limitations under various conditions, with discussions of the problems encountered and their solutions.

These papers are all being written by officials and engineers of the mining companies in accordance with an outline prepared by the Bureau of Mines for the purpose of obtaining uniform and comparable data.

Scott Turner
SCOTT TURNER,
Director.

Circular No. 6107,
March, 1929.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

MINING PRACTICE AT MORENCI BRANCH, PHELPS DODGE CORPORATION, MORENCI, ARIZ.[1]

By McHenry Mosier and Gerald Sherman[2]

INTRODUCTION

This paper describing mining practice at Morenci, Ariz., is one of a series of articles on mining methods and practice in the various mining districts in the United States.

At present (1929) practically all the mineral production in the Morenci district is from the Humboldt mine of the Morenci Branch, Phelps Dodge Corporation. The mining method used is adapted to the type of ore body being exploited; it has been developed by adopting methods used elsewhere and making necessary changes to fit local conditions. Improvements in current practices are still being made.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of L. F. Hersey, chief engineer, mining department, and C. P. Burford, engineer in charge of stope control, both of the Morenci Branch; and of E. D. Gardner, supervising engineer, and C. H. Johnson, assistant mining engineer, United States Bureau of Mines at Tucson.

HISTORY OF THE DISTRICT

The Clifton-Morenci district is in southeastern Arizona on the southern slope of the Gila Range of mountains, near the junction of the Gila and San Francisco Rivers. Its elevation is 4,800 feet. Clifton is about 69 miles by rail northwest of Lordsburg, N. Mex., on the Southern Pacific Railroad. Morenci is served by a narrow-gauge freight railroad from Clifton (fig. 1).

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1 The Bureau of Mines will welcome reprinting of this article but requests that the following footnote acknowledgment be made: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"

2 Consulting engineers, U. S. Bureau of Mines.

Gold was discovered in 1872 by a party of prospectors from Silver City, said to have been connected with the U. S. Army. Copper ore indications were noted on Copper Mountain, and several claims were staked, for copper ore but because of the lack of rail transportation in the early days, the first real interest was in gold. The first copper smelting began in 1873 when a cupola furnace having a capacity of 1 ton per day was built, but only the very richest ores could be treated.

The railroad was built through Lordsburg in 1881, and a branch line was extended to Clifton in 1884. The building of the railroads stimulated mining in the district by decreasing operating costs. In 1882 both the Detroit Copper Co. and the Arizona Copper Co., Ltd., were organized. In 1900 the Shannon Consolidated Copper Co. began operations.

The first smelters in the district treated copper oxide ores mined from sedimentaries near the main porphyry contact. In 1893 chalcocite ore bodies were opened in the Copper Mountain porphyry. As the rich oxide ores became depleted, attention was directed to the lower-grade ores in the porphyry. The first concentrator was built in 1886.

In 1922 the Arizona Copper Co., Ltd., which had previously absorbed the Shannon Copper Co., merged with the Phelps Dodge Corporation, whose Morenci Branch was originally the Detroit Copper Co. Important economies in operations were made possible by this consolidation for the following reasons: (1) On account of contiguous ore bodies, which are now being mined as single units by cheaper methods at a more intense rate; (2) by milling all ores at one concentrator, remodelled to treat efficiently the present ores; (3) by smelting ores and concentrates at one modern plant; and (4) by reducing overhead and certain operating costs through the elimination of duplication, as one organization now serves in the place of two.

In the production history of the district there have been three periods:

(1) From the discovery of the mines until the construction of the railway. During this time only the rich oxidized ores from the sedimentary rocks and from surface veins in the porphyry could be mined and smelted on the ground.

(2) From the construction of the railway in 1884 until about 1915. This covers the period of the concentration of comparatively rich sulphide ores while the production of direct smelting ores still continued in important quantities.

(3) Since about 1915 the smelting ore has shrunk to insignificant proportions, and the production has been made from secondarily enriched, but leaner, sulphide ores from unoxidized areas in the porphyry.

PRODUCTION

The annual production from the district attained its peak in 1916, with 70,000,000 pounds of copper. At present the output is almost 60,000,000 pounds per year; it is produced by concentrating 1,500,000 tons and by smelting a small tonnage of furnace ores and converter flux. To the end of 1927 the district had produced a total of approximately 1,800,000,000 pounds of copper.

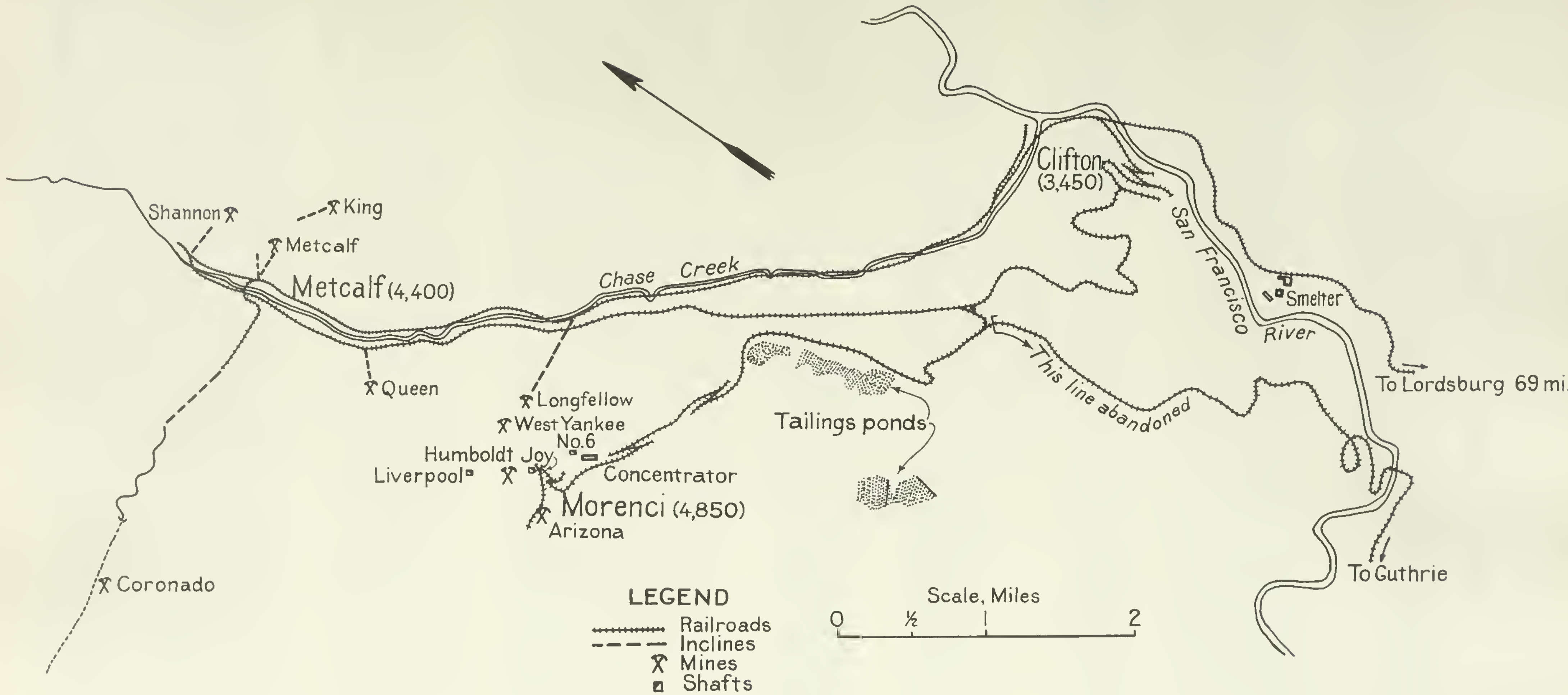


FIGURE 1.—Clifton–Morenci District

GENERAL GEOLOGY OF MORENCI DISTRICT

In the Morenci district, as distinguished from the Metcalf and Coronado deposits, copper mineralization was introduced with or after the intrusion of a large mass of porphyry below a series of sediments.

Rich, irregular ores, often oxidized, were found in the limestone and shales adjoining the porphyry contact. Surface veins of good ore also outcropped on the exposed surface of the porphyry. These ores supported the mines during the early days. The large deposit of concentrating ore at the Humboldt mine, which now is being worked, lies deeper in the porphyry and is localized by major systems of faults and fractures.

The deposit is comparatively shallow and lies wholly above the level of the deep channel of Chase Creek which passes a short distance to the northeast.

The Humboldt Mine

The Humboldt mine, which was the principal source of copper of the Arizona Copper Co. and is now of the Morenci Branch of the Phelps Dodge Corporation, is in the center of the town of Morenci at the foot of Copper Mountain. The mine has been worked almost continuously for nearly 40 years.

The country rock at Morenci is a quartz monzonite porphyry and a series of sedimentary rocks consisting of limestone, shale, and quartzite generally metamorphosed. The porphyry is intrusive and occurs as a large mass and also as dykes in the sediments in the contact zone.

The ore bodies of the Humboldt mine are in the main porphyry area a few hundred feet northwest of the contact with the altered sediments. The porphyry contains many small detached bodies of metamorphic limestone and shale. The porphyry has a close structural and genetic connection with the ore deposits; a porosity and looseness of grain have made it easily permeable to ore-bearing solutions. Fresh rock occurs rarely, and a large part is completely altered to sericite, quartz, and pyrite, chalcocite being usually associated with the latter mineral.

Chalcocite is the only important ore mineral in the mine. In the upper levels of the chalcocite zone, green films of malachite and brochantite are commonly found. In this mine the chalcocite gives clear evidence of being secondary and occurs deposited on pyrite, beginning as slight black films and gradually replacing the mineral entirely.

Fissures cut through the metamorphic rock as well as the porphyry, but in the former they are rarely productive, the softened porphyry being evidently the most favorable ground for ore. The rich seams consist of pyrite, containing more or less chalcocite but very little quartz. Frequently they are bounded by well-defined planes with evidence of movement and also may be traversed by slips parallel to the walls. The wall rock immediately adjoining the rich seams is, in some cases, converted to almost pure kaolin. This mineral, however, does not exist as a constitutent of the rock. On both sides of these seams extends a mass of sericitized porphyry, of varying widths, containing little seams and grains of chalcocite.

The ore body now being mined is in zones of fracturing and has no definite walls. The limit of the ore is determined by assay. Irregular fracturing occurs in three directions, but the fracture planes have been more or less recemented with quartz and pyrite. The planes of weakness run from 2 to about 18 inches apart.

Permanent drifts and raises in the ore body have to be timbered. Temporary workings generally stand without timber.

The present ore reserves lie principally in one mass in the porphyry, striking irregularly N. 25° E. along two intersecting fault zones through a maximum length of 2,000 feet and a maximum width of 600 feet. The vertical range is about 1,000 feet. The ore body, throughout the northern portion where it follows the Copper Mountain fault, dips 65 to 75° to the eastward, while at the middle and to the south, along the Fairplay fault, it is nearly vertical. The ore body pitches northward along the Copper Mountain fault.

Much of the porphyry wall rock carries at least 0.4 per cent copper. It is generally stronger than the ore physically, because it is less altered, and carries less kaolin and sericite.

Above the 5th level the southeastern edge of the ore body lies against the main porphyry-sedimentary contact, while below that level and to the northward the ore lies at an increasing distance from the contact. The contact is highly silicified and consequently the ore along it is hard and breaks coarsely. Conversely, ores with increased alumina break more finely.

The capping is occasionally soft hematite, but this material usually contains enough silica to prevent packing, as is indicated by the gob in old square-set stopes and by the waste, following down after former top-slice stopes.

The present lift of the ore body being worked is situated for the most part either (1) under top-slice stopes with overlying timber mats, or (2) below sub-level caving stopes immediately beneath those top slices. The timber mats are of no assistance in preventing dilution and, furthermore, cause delays at the grizzlies and even in the chutes below. The timber also interferes with flotation.

Although the ore in the Humboldt mine is somewhat harder than at other porphyry mines in the Southwest its caving is made possible by the major faults with their sympathetic sheeting, by the universal jointing throughout the ore body, by the minute fracturing of the ore in all directions, and by the alteration of the ore.

The grade of the ore reserves is about 1.90 per cent total copper with .20 per cent acid-soluble copper. Near the bottom of enrichment the ore is slightly higher grade. In depth it carries somewhat more alumina, and the acid-soluble copper content decreases.

The average composition of the ore going to the mill is:

	Per cent
Silica	65
Alumina	17
Potash	5

The ore contains 3.5 per cent moisture as it leaves the mine. Due to sericite, the alumina content of the ore is unusually high, and when finely-divided ore is wet it tends to stick in the chutes and to hang up in raises.

METHODS OF PROSPECTING AND EXPLORATION

In the exploration and development of the large and comparatively regular low-grade Humboldt ore body the first work was unsystematic and was done in the search for high-grade ore. When the present low-grade ore became of importance, information gained in the former work was used and supplemented by systematic work to prove the assay grade, size, and outline of the ore body.

The thorough exploration of ore deposits to be caved is necessary because operations must be planned in advance for the whole operation. A large part of the cost of mining is incurred before production begins, and plans can not be changed to suit unexpected conditions.

The Humboldt ore was explored entirely by underground drifts and raises. Churn drills have been used elsewhere in the district, and a separate ore body is now being explored by diamond drills.

METHODS OF SAMPLING AND ESTIMATING TONNAGE AND GRADE.

Underground openings, such as drifts and raises, are sampled by cutting channels in the ore with hand hammer and moil. Care is taken to cut the channels perpendicularly to the vein structure. As the porphyry is cut by numerous tiny veins, the channels have no regular directions relative to the workings. Some are parallel to the floor about waist high; others are cut diagonally across the back. Each sample represents 10 feet of drift or raise.

In diamond drilling, 50 per cent of the core is recovered which does not truly represent the ground drilled. This has made it necessary to save all the core and a known fraction of the sludge from every sampling interval. These are combined according to weights and grades to obtain the average grade of each sample. The sludge is split, to deliver one-eighth of the water and rock from the hole, with a splitter especially constructed for the work. The resultant sludge is allowed to settle in barrels until the water is clear. The water is then decanted off and the sludge evaporated to dryness in an electric drying oven. The dried sample is ground, mixed, and assayed. Tests are made periodically of the water decanted from the sludge.

To obtain the final assay for any sampling interval the following procedure is used: First, the core is weighed and put through the crusher and rolls in the sample mill. The resultant pulp is carefully mixed and split to a 3-ounce sample which is ground to -200 mesh and sent to the assay office for electrolytic assaying for total and acid-soluble copper. The reject is placed in an air-tight can for possible future reference. Second, the sludge is dried in electric dryers, weighed and carefully mixed and split to give another 3-ounce sample for pulverizing and assaying similarly to the core sample. The remaining pulp is also filed in an air-tight can. Third, a known percentage of the water decanted from the sludge is evaporated to dryness, weighed, and assayed to check the possible loss of sludge held in suspension and carried off by the water rejected. Fourth, the average copper content of the sample is determined by combining the assays of the core and sludge in proportion to their weights. If the weight of the sample does not correspond with the calculated weight of the section of the hole drilled the results may not be given full weight. Adjustments are made in using these results as well as the results of individual samples that are unusually high in copper.

For the estimation of ore reserves a full knowledge of the ore deposit must be obtained. Caving stopes have reasonably regular outlines, and selective mining is therefore not practicable by this method.

Some material of a grade that will not pay to reduce must be mined, and some good ore on the boundaries must be left because its inclusion would bring in too much waste. The side boundaries, which are vertical or nearly vertical, are drawn as compromise planes to inclose as much ore as possible without too much waste.

Except for preliminary estimates, the volume of material within the stope outlines constitutes the ore reserves which are bounded by (1) the undercutting level, (2) the shrinkage side outlines, and (3) the leached gossan or a stope above as the case may be. Within these boundaries the grade of ore in place is calculated by combining assays in a rational manner.

DEVELOPMENT WORK

The mine is worked through three shafts and has two adits. Figure 2 is a vertical diagrammatic sketch of the mine. Ore only is hoisted through No. 6 shaft. Supplies and men are handled through the Joy shaft, and the Liverpool shaft is used mainly for handling waste and supplies and men doing development work on the lower levels. The main shafts are located at such distances from the ore body that they will not be affected by ground movement due to the caving system of mining in use.

The present development system is the outgrowth of former operations in more scattered locations.

The porphyry is fairly uniform in the mineralized section. Due to the planes of weakness the rock is broken readily by explosives.

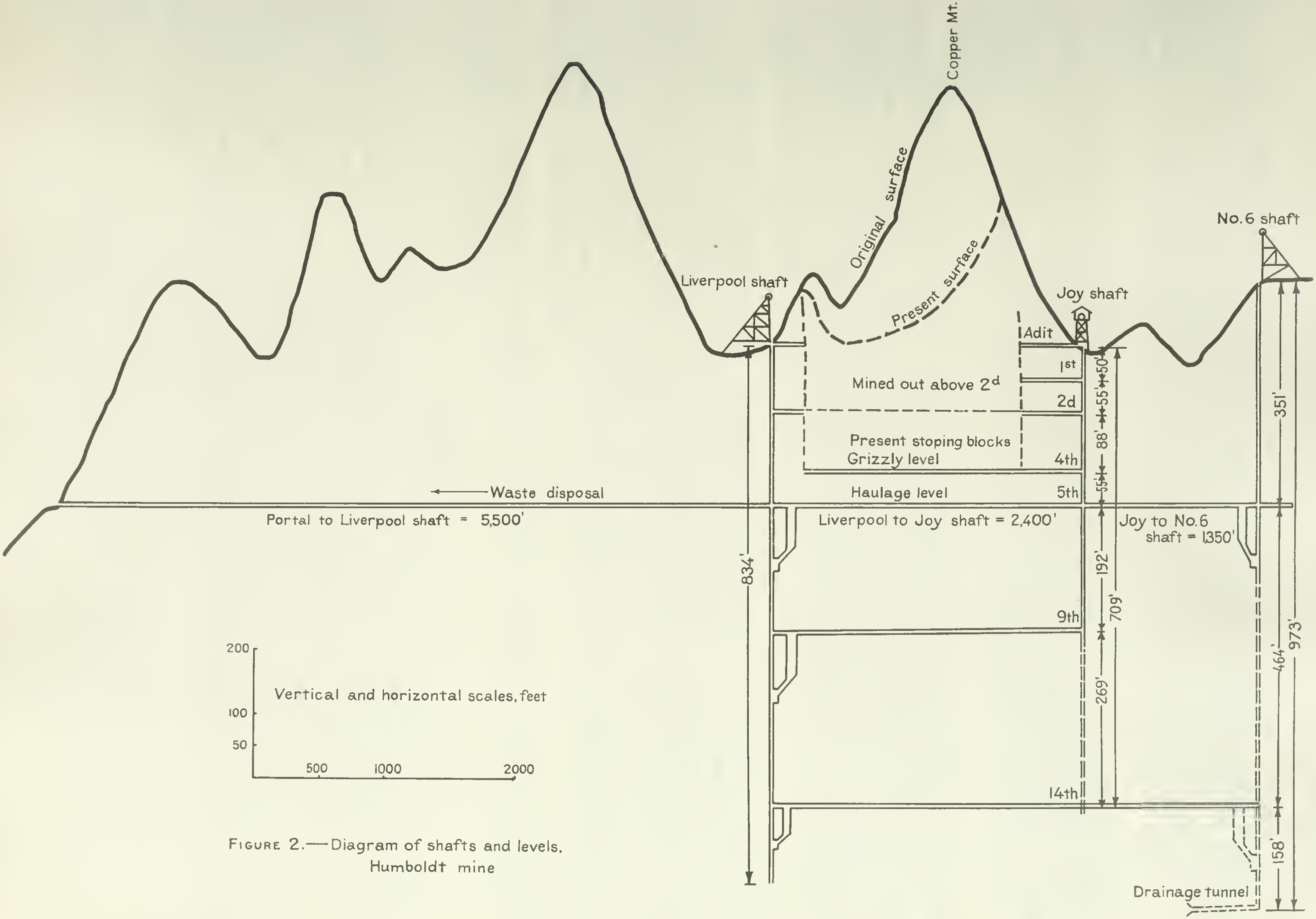


Figure 2.—Diagram of shafts and levels, Humboldt mine

The stope development work and the haulage drifts under the stopes are in the porphyry and have been generally in ore. Development work and long haulage drifts are also driven in limestone, quartzite, and granite. The granite through which a drainage tunnel is being driven contains few planes of weakness and is very difficult to break. The other rocks are harder to break than the mineralized porphyry.

Development work is planned far enough ahead so that one operation does not interfere with another. Generally a miner is given two or three faces in which to work. With three faces available, miners frequently drill $1\frac{1}{2}$ to $2\frac{1}{2}$ rounds per shift. In drifting it is desired only to blast as deep a round as can be shoveled out in one or two complete shifts. This leaves a clean set-up for drilling the next round.

Standard rounds for all development work are of the same general type; the modifications are in the number of holes used. A standard is available for any type of ground that may be encountered. The V-cut round is used, and care is taken to make the cut holes meet to insure simultaneous detonation. This is especially necessary when gelatin dynamite is used, because it is relatively insensitive to shock. Cut holes are drilled in the center to take advantage of the most freely-breaking area in the face.

The amount, distribution, and grade of explosive used are also standardized. The standards were obtained after making many experiments in different classes of ground, and it is considered that by the consistent use of the standards set greater economy can be obtained. Occasionally a heading could be broken by a round with fewer holes or with less explosive; however, a few failures are more than offset by the advantages gained. The miners readily learn to drill standard rounds. The bosses advise the men in the selection of the round and specify the quantity and kind of powder to be used.

Practically all development work is done on contract. A uniform price is set for each class of work.

Drilling

Drift rounds in large headings or in hard rock are usually drilled with drifting machines mounted on vertical columns. It is considered that they can be drilled more nearly to the standard by using columns than with crossbars. Small drift headings and some of the larger headings in the easily broken rock are drilled with unmounted jackhammers. In most cases where an unmounted drill is used its weight is supported on a length of drill steel. A small hook is used for attaching the drill to the steel; one end of the hook fits around the end of the steel above the lug and the other end under the frame of the drill. As different lengths of steel are always available at the face, the holes can be started at any desired height.

In average Morenci ground, which drills easily, the jackhammer type drill gives excellent service. In the quartzite and granite occasionally encountered in the lower levels, drifting machines have proved more satisfactory; they drill faster, maintenance costs per foot of advance are less, and fewer pieces of steel per hole drilled are used.

Drills of the jackhammer type are used in sinking shafts and winzes. Raises are run with stopers. Hand-rotating machines are generally employed but self-rotators are used in the hardest ground.

The drill-repair shop is under the direction of the development department and spare drills in good condition are always available at tool houses located at convenient points in the mine.

Steel.- Only hollow drill steel is used. Seven-eighths-inch hexagonal steel is used for jackhammers, and the same size of quarter octagon for the stopers. One-inch round steel is used for drifters in rock other than porphyry. The gauge of starters is 1-15/16 inches; the reduction in diameter for each succeeding bit is 1/16 inch. The difference in length between each change is about 15 inches. Bits are sharpened carefully, so that variations in the diameters of different bits are less than 1/64 inch.

Drill Bits.- A double taper bit having angles of 8 and 14°, with flattened wings, has been developed at Morenci (fig. 3). The porphyry is easily drilled, and the usual type of drill bit will lose its gauge before the cutting edge is dulled. It is considered at Morenci that the flat-wing type of bit drills faster with less loss of gauge than the standard form. In soft ground the side-hole bit is used.

Air Pressure.- The air pressure at the compressors is 90 pounds per square inch and at the drills is 80 to 85 pounds.

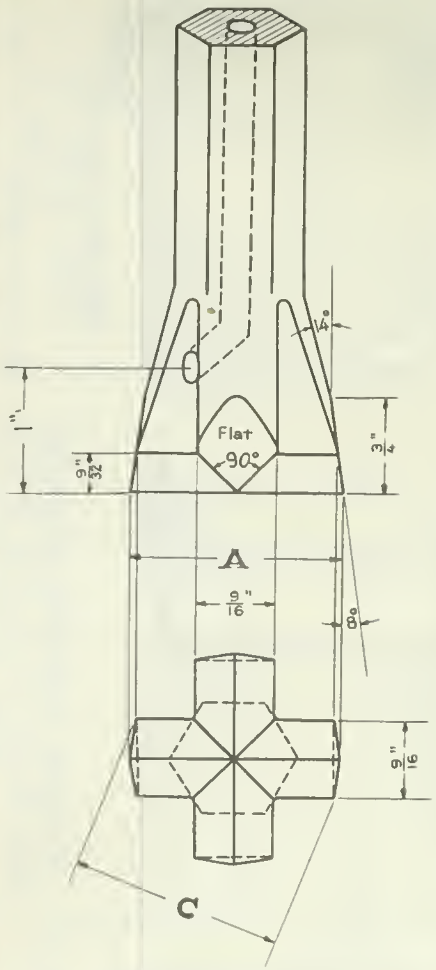
Blasting

Loading Holes.- A standard method of loading holes is followed for all rounds. Primers with fuse and detonators are made up by inserting the detonator in the side of the primer cartridge and securing it in place by tying or taping the fuse to the cartridge. The primer is placed as the second stick from the bottom in each hole.

Explosives.- Drift rounds in the ore are generally blasted with 27 per cent balanced dynamite or 40 per cent strength ammonia dynamite in harder ground. For [illegible] per cent strength gelatin dynamite is used in raises. The cut holes of rounds in hard rock are blasted with 80 per cent strength gelatin dynamite, if necessary, and the other holes with 40 per cent strength of the same explosive. Cut holes of long rounds are loaded with 80 per cent gelatin. The correct amount of powder for each round is issued to the miners upon the order of the shift bosses.

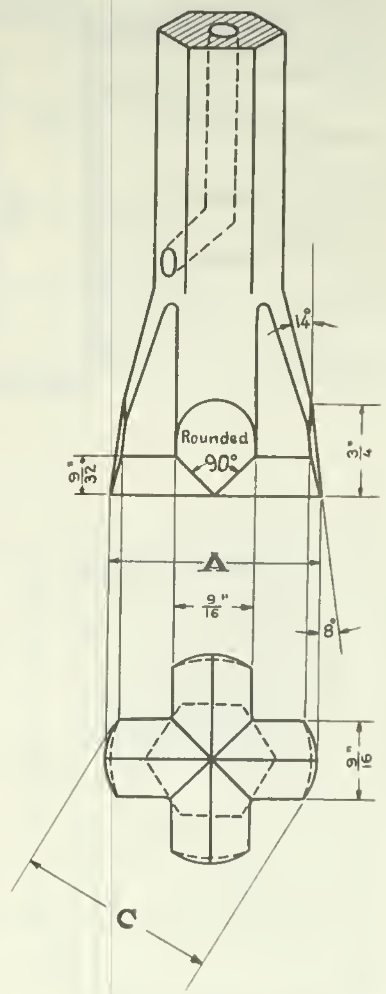
Detonators.- All blasting in raises over 30 feet high and in shafts is done with electric delay detonators. Some drift rounds are also blasted in this manner.

Flat shoulder



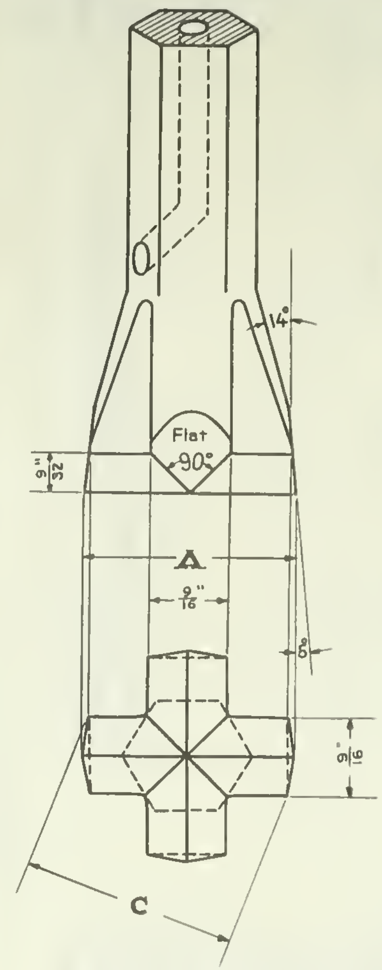
Length	Size of bit	
	A	C
2'-6"	$1\frac{11}{16}$"	$1\frac{11.26}{16}$"
3'-9"	$1\frac{10}{16}$"	$1\frac{10.32}{16}$"
5'-0"	$1\frac{9}{16}$"	$1\frac{9.38}{16}$"
6'-3"	$1\frac{8}{16}$"	$1\frac{8.43}{16}$"
7'-6"	$1\frac{7}{16}$"	$1\frac{7.52}{16}$"
8'-9"	$1\frac{6}{16}$"	$1\frac{6.60}{16}$"

Round shoulder



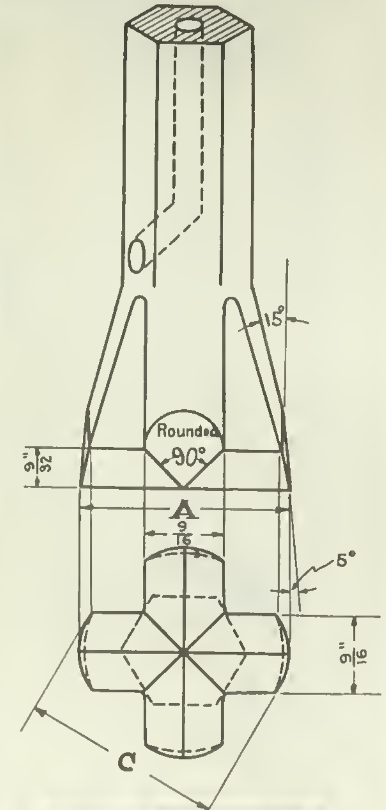
Length	Size of bit	
	A	C
2'-6"	$1\frac{11}{16}$"	$1\frac{9.74}{16}$"
3'-9"	$1\frac{10}{16}$"	$1\frac{8.74}{16}$"
5'-0"	$1\frac{9}{16}$"	$1\frac{7.74}{16}$"
6'-3"	$1\frac{8}{16}$"	$1\frac{6.74}{16}$"
7'-6"	$1\frac{7}{16}$"	$1\frac{5.74}{16}$"
8'-9"	$1\frac{6}{16}$"	$1\frac{4.74}{16}$"

Flat shoulder



Length	Size of bit	
	A	C
2'-6"	$1\frac{11}{16}$"	$1\frac{11.72}{16}$"
3'-9"	$1\frac{10}{16}$"	$1\frac{10.77}{16}$"
5'-0"	$1\frac{9}{16}$"	$1\frac{9.84}{16}$"
6'-3"	$1\frac{8}{16}$"	$1\frac{8.90}{16}$"
7'-6"	$1\frac{7}{16}$"	$1\frac{7.97}{16}$"
8'-9"	$1\frac{6}{16}$"	$1\frac{7.05}{16}$"

Round shoulder—Original



Length	Size of bit	
	A	C
2'-6"	$1\frac{11}{16}$"	$1\frac{10.21}{16}$"
3'-9"	$1\frac{10}{16}$"	$1\frac{9.21}{16}$"
5'-0"	$1\frac{9}{16}$"	$1\frac{8.21}{16}$"
6'-3"	$1\frac{8}{16}$"	$1\frac{7.21}{16}$"
7'-6"	$1\frac{7}{16}$"	$1\frac{6.21}{16}$"
8'-9"	$1\frac{6}{16}$"	$1\frac{5.21}{16}$"

FIGURE 3. Double taper drill bits

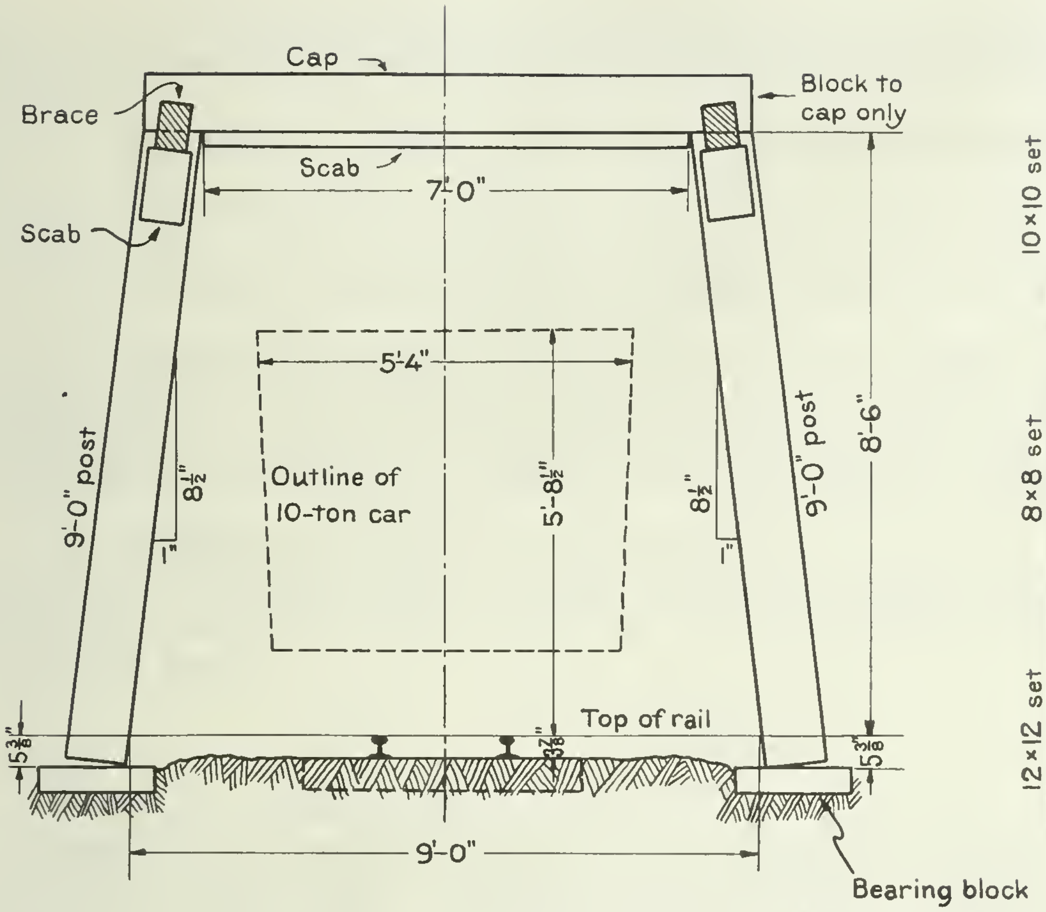
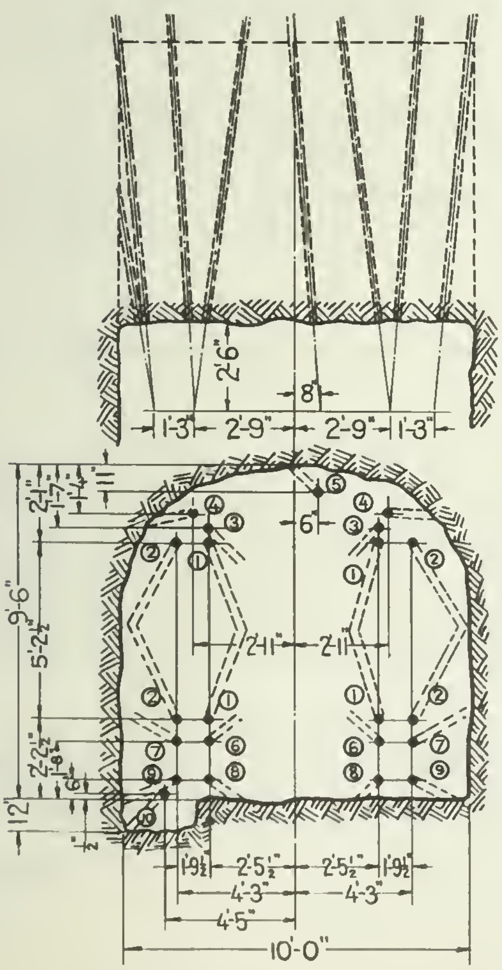


FIGURE 4.—5th level standard drift set

LIST OF TIMBER FOR 1 SET

Set		PIECES	NO.	DESCRIPTION	BO. FT.
10×10 set	2	Posts	39	10x10x9-0 Batter 1 End As Shown	150.0
	1	Cap	42	10x10x8-8 Sq Ends	72.2
	1	Scab	128	2x10x7-0 " "	11.7
	2	Scabs	44	2x8x1-0 " "	2.7
	2	Braces	63	6x8x4-2 " "	33.3
	2	Bearing Blocks	45	4x12x1-8 " "	13.3
				TOTAL BOARD FT.	283.2
8×8 set	2	Posts	46	8x8x9-0 Batter 1 End As Shown	96.0
	1	Cap	49	8x8x8-4 Sq. Ends	44.3
	1	Scab	11	2x8x7-0 " "	9.3
	2	Scabs	44	2x8x1-0 " "	2.7
	2	Braces	62	6x8x4-4 " "	34.6
	2	Bearing Blocks	45	4x12x1-8 " "	13.3
				TOTAL BOARD FT.	200.2
12×12 set	2	Posts	52	12x12x9-0 Batter 1 End As Shown	216.0
	1	Cap	55	12x12x9-0 Sq. Ends	108.0
	1	Scab	27	2x12x7-0 " "	14.0
	2	Scabs	44	2x8x1-0 " "	2.7
	2	Braces	61	6x8x4-0 " "	32.0
	2	Bearing Blocks	45	4x12x1-8 " "	13.3
				TOTAL BOARD FT.	386.0



183 feet of drilling

Blasting chart

Holes	Order of firing	Kind of powder and amount per hole					
1	First						
2	Second						
3	Third						
4	Fourth						
5	Fifth						
6	Sixth						
7	Seventh						
8	Eighth						
9	Ninth						
10	Tenth						

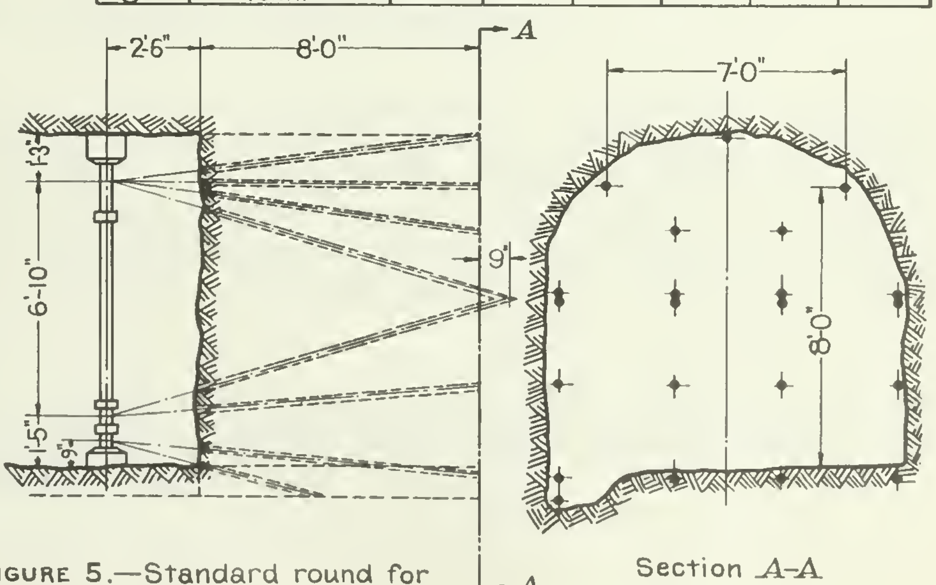


FIGURE 5.—Standard round for 9' 6"× 10' drift, 8' 0" break (21 holes + 1 short hole for ditch)

Section A-A

All blasting in pillars on the undercutting level, on grizzlies, and in hung-up raises is by means of instantaneous electric detonators.

All blasts, except block holes, are detonated by No. 8 straight caps.

Fuse with No. 8 detonators are used in most drift work.

The caps of all electric detonators used in rounds are No. 8 in strength.

Rounds are blasted from the mine circuit of 250 volts. A special circuit-breaker switch for electric blasting is used, which breaks the circuit automatically and almost instantaneously after being applied in the blasting circuit. Since this switch was adopted no trouble from side-spitting has occurred.

Stemming.- Stemming in cartridge form is used in all rounds. The cartridges are made by packing a powder box full of paper shells with open ends upward. The shells are then filled with fine sand tailings and the ends of the shells closed by hand.

Drifts

The contracts for driving drifts are generally divided into two parts: (1) Breaking and removing the rock; (2) timbering, including squaring out the section. Occasionally, where the ground requires timbering close to the face, breaking and timbering are included in the same contract.

Three general types of drifts are run: (1) Motor haulage, 10 by 10 feet in cross section; (2) supply, 6 by 8 feet in cross section; and (3) grizzly and undercutting, 4 by 6 feet in cross section.

Motor Haulage Drifts.- The motor haulage drifts are generally broken 10 by 10 feet in cross section in the timbered sections, and 8 by 9 feet in untimbered sections. The timbered sets under the stopes are 8 feet 6 inches from the rail to the bottom of the cap (fig. 4).

The depth of the round broken depends upon the cycle of operations desired and the condition of the ground in regard to timber support.

In ground where falls from the back may occur before the round is mucked out, protection is afforded the workmen by means of booms or stringers. After the round is shot the cap and top lagging for the next set is put in place and rested on two booms. The stringers are supported under the cap of the last set stood by heavy bars of iron bent to fit the stringers; the two ends are turned to hook over the top of the cap. The rear ends of the stringers are blocked down under the cap of the second set from the face.

After the broken rock is removed, the posts of the sets are stood and the cap is lowered on the posts by knocking out the blocking over the rear end of the stringers. Figure 5 shows a standard 8-foot drift round.

Grizzly Drifts.- Raises are run from the haulage drift to reach the bottom of the grizzly drifts at intervals of 14 or 21 feet before those entries are extended. Most of the ore broken by blasting falls into the raises. The rest is shoveled into them.

Undercutting Drifts.- After the finger raises are put up the undercutting drifts are run. The tops of the raises are on 14-foot and 18 2/3-foot centers. The undercutting drifts are advanced by the same method as on the grizzly level. The costs are less, as the raises for receiving the broken ore are closer together and the undercutting drifts are not timbered except for an occasional stull.

Use of Mechanical Loader.- The rate of advance of any single heading is generally dependent upon the time required for the removal of the rock broken by blasting. A very material saving in time was made by using a mechanical loader while advancing the 14th-level main heading.

The shovel used in this work has a capacity of 30 tons per hour. It consists of a frame similar to that of a mine locomotive supporting a conveyor and scoop, and is electrically driven. Unlike many other types of mechanical loaders it does not clamp to the rail, but it travels back and forth on the track during operation. As the shovel is moved forward the scoop digs into the pile of broken material. As it moves back again the scoop is raised, and the rock slides to a conveyor belt which discharges into the mine car. Power is transmitted through sprocket chains and clutches. The movement of thrusting the scoop into the muck pile is accomplished by driving the whole machine forward on the tracks, which avoids the complicated differential motion necessary in other small power loaders.

Organization of the drifting work on this level had to be completely changed to make the best use of the mechanical loader, and as a direct result it was some time before an acutal gain in daily advance was obtained. However, between February 1, 1928, and September 30, 1928, 2,543 feet was driven in the main heading, having an average rectangular cross section of 10 1/2 feet in width and 9 1/2 feet in height. Approximately 9 tons of rock was broken per foot advance. The actual daily advance was 11.3 feet, as compared to 7.3 feet by hand-shoveling, which constituted a gain of 54.8 per cent. Delays during working periods for emergency repairs to the shovel averaged less than 15 minutes per shift.

Previous to installing the loader, four men were employed on the shoveling crew, two mucking and two handling the cars. Progress was slow and discouraging to the muckers because of water in the heading which was being driven down-grade. This work, so distasteful to the men, was eliminated by the use of the mechanical loader. The best crew for the loader consisted of three men, one man handling the main controls, one man tending empty and loaded cars, and one man dividing his time between handling the dipper controls and tramming.

The drifts were wide enough to permit double track for 1-ton cars, which insured a good supply of cars to the loader. A portable switch or crossover (fig. 6) was used, which reduced the delay while cars were being trammed to and from the loader.

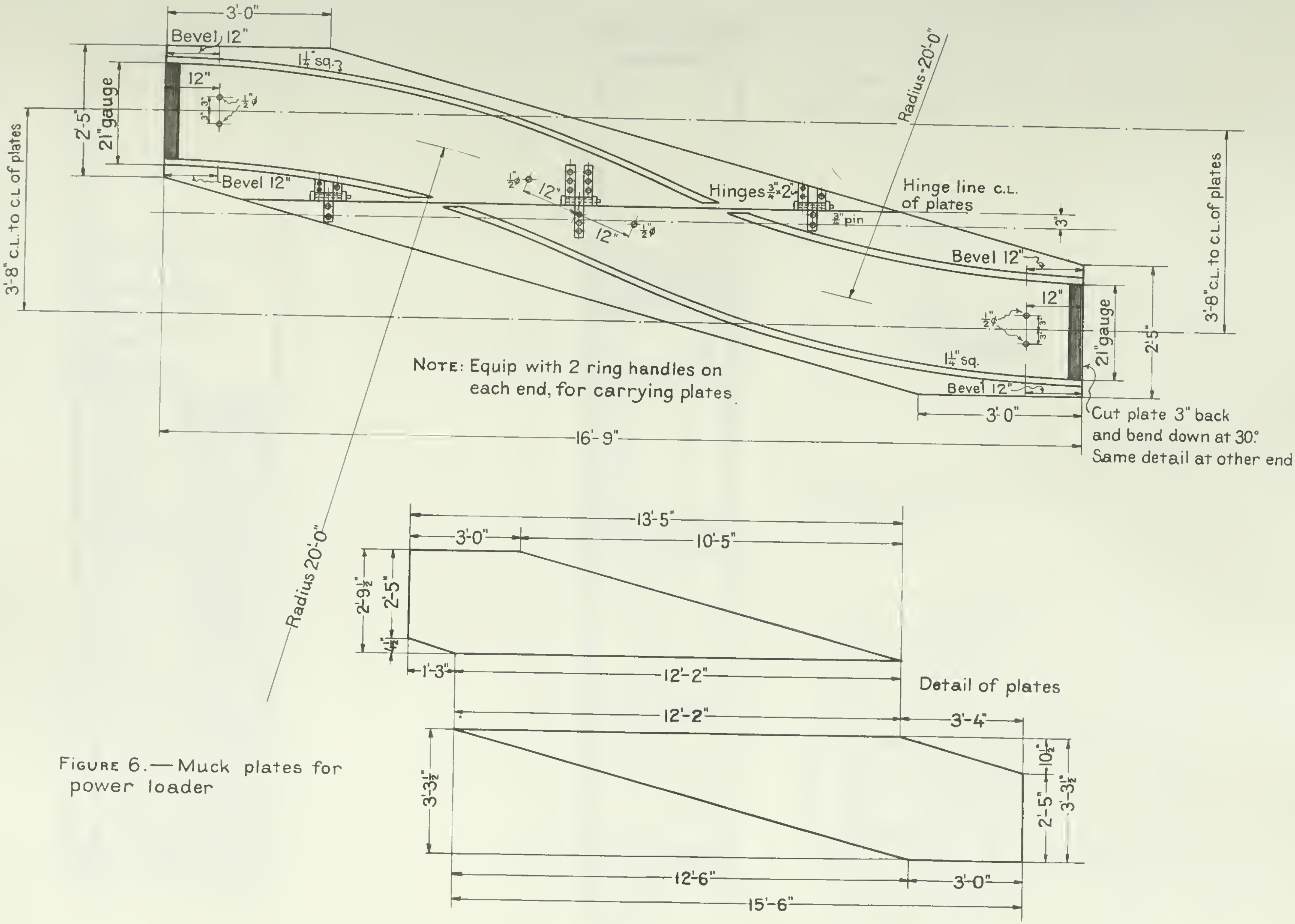


Figure 6.—Muck plates for power loader

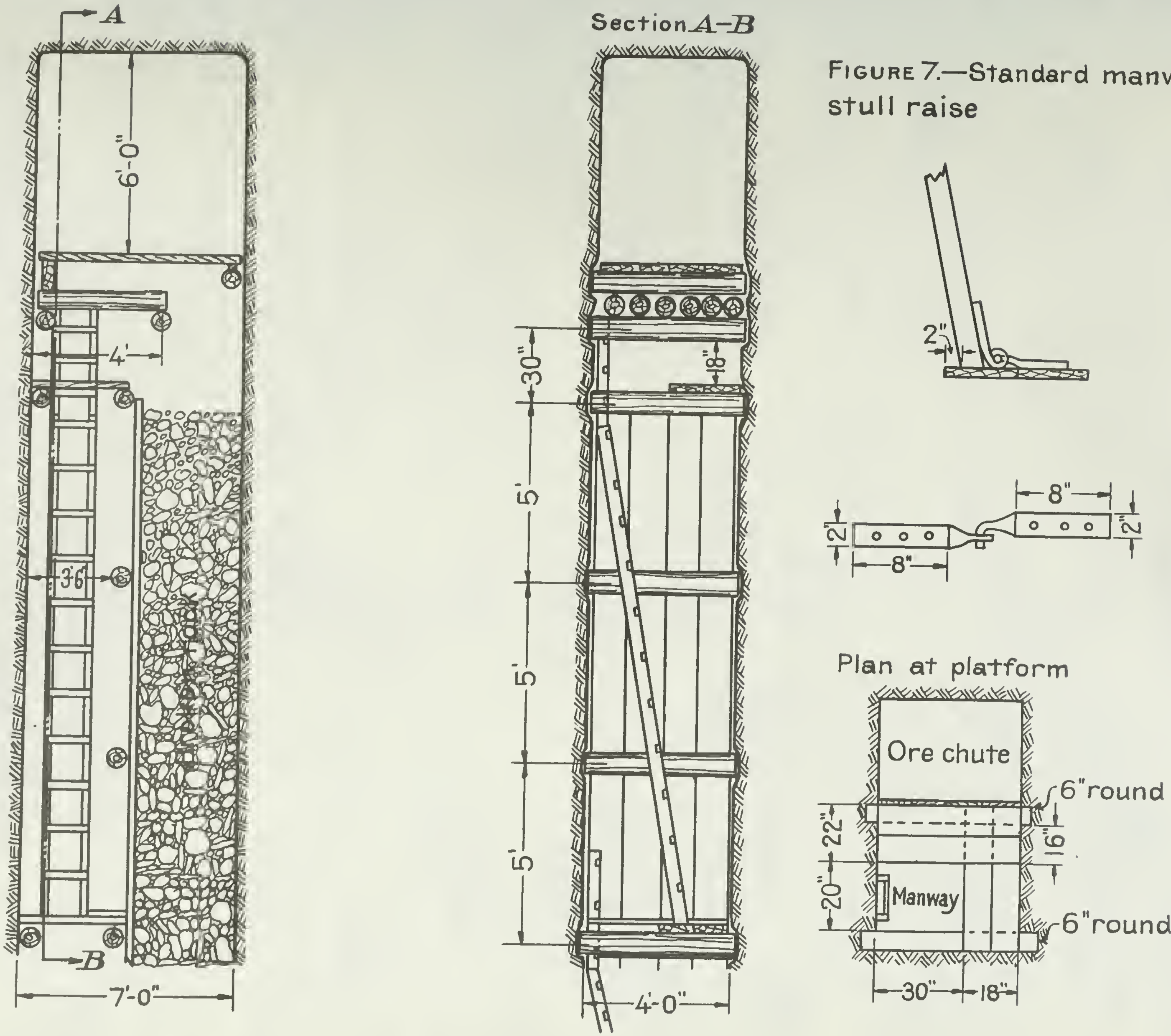


Figure 7.—Standard manway stull raise

Ordinarily two complete cycles were made per day--that is, two rounds were drilled and shoveled out in each 24 hours. The following tabulation gives the average total time spent on each operation for the 12 hours required to complete a cycle:

Operation	Time (hrs. and min.)
Setting up	0.45
Drilling	3.30
Loading and firing.	.45
Tearing down	.15
Waiting for smoke to clear	.45
Mucking	6.00
Total	12.00

The relative distance mucked per man shift in a section 1,788 feet long where hand-shoveling was used and in 2,343 feet run with the loader was 1.65 and 1.80 feet, respectively. Although when the loader was used a slight increase in feet mucked per man-shift was apparent, the actual driving efficiency dropped. This was due primarily to the necessity of speeding up operations and consequently resulted in the unavoidable crowding of men in the face. Although the result was a drop in the efficiency for this size of heading the decrease was more than offset by the increase in daily advance. This crowding in the face also increased the cost per foot of advance. The loader proved successful, as the work was done in 114 less operating days than would have been necessary had all hand labor been employed.

This operation was planned for rapid progress. Lower mucking costs may be obtainable by reducing the number of men and adapting the organization to the most efficient mucking rate.

Raises

From the experience in the district it has been found that ore transfer raises run at an angle of 70° are the most satisfactory, as at this inclination the ore neither builds up on the bottom side of the raise nor packs in the chutes.

Raises 4 by 6 feet in cross section and 50 feet high for ore chutes are run either vertically or on an incline of 75° from the haulage drift to the grizzly level and are not ordinarily timbered. The inclination used fits the spacing of the grizzlies. Where the ground will not stand the raises are cribbed. One man drills and blasts a round in these raises in a shift or less and generally breaks about 4 feet. No water or air pipe lines are taken up these raises. A round generally consists of 9 holes, which are each loaded with four or five cartridges of 40 per cent gelatin dynamite.

Figure 7 shows the details of the pilot raise for shrinkage stopes.

Pilot raises are used for making shaft connections. After the connections are made the raises are enlarged to full shaft size, beginning at the point of connection and carrying the timbering downward.

For distances of over 200 feet, raises are run with three compartments. The size of the compartments and the timbering details are shown in Figure 8. One compartment is used for holding the broken rock, the middle one is a manway, and the third compartment is used for a light cage to handle men and supplies used in the raise. Stations are cut every 100 feet. As soon as a raise has progressed 30 feet above a substation, the sheave for the hoist is raised and hoisting is done to that level.

To reduce the excessive weight of broken rock at the bottom of the chute of such a long raise, rock is transferred through auxiliary chutes spaced 100 feet apart.

All raise rounds are blasted electrically, using five delays. Before loading the holes the miner doing the work obtains the only key to the lock of the blasting switch. After the round is loaded the man in charge connects the lead wires to the blasting line 25 feet from the bulkhead, where a second man is stationed. These men then descend to an interrupter switch at the bottom of the raise. After the approaches to the raise are guarded the interrupter switch is closed and the round blasted through the main blasting switch.

The back of the raise is never more than 12 feet above the timber. After a round is blasted a 5-foot set is put in place; on top of this a blasting set is installed, and then the next round is drilled. The broken rock in the raise is kept within 6 feet of the bulkhead. Just before blasting, enough rock is drawn from the chute to provide space for the material broken by the blast.

Shafts

The Liverpool shaft was sunk first, and development of the lower levels of the mine proceeded from it. The other shafts are deepened by first driving pilot raises from the lower

The main shafts of the Humboldt mine are shown in Figure 2. No. 6 shaft contains two 5 by 6 foot hoisting compartments and one 5 by 5 foot manway. All ore for the mill is now hoisted from the 5th level, but plans are under way for deepening the shaft by raising from the 14th level.

The Joy service shaft has one 7 by $13\frac{1}{2}$ foot cage compartment and one $5\frac{1}{2}$ by $13\frac{1}{2}$ foot compartment divided for the cage counterweight and for pipes, wire conduits and a ladderway. The cage is large enough to take a truckload of timber and will carry 60 men comfortably.

The Liverpool shaft has two compartments above the 14th level and three below.

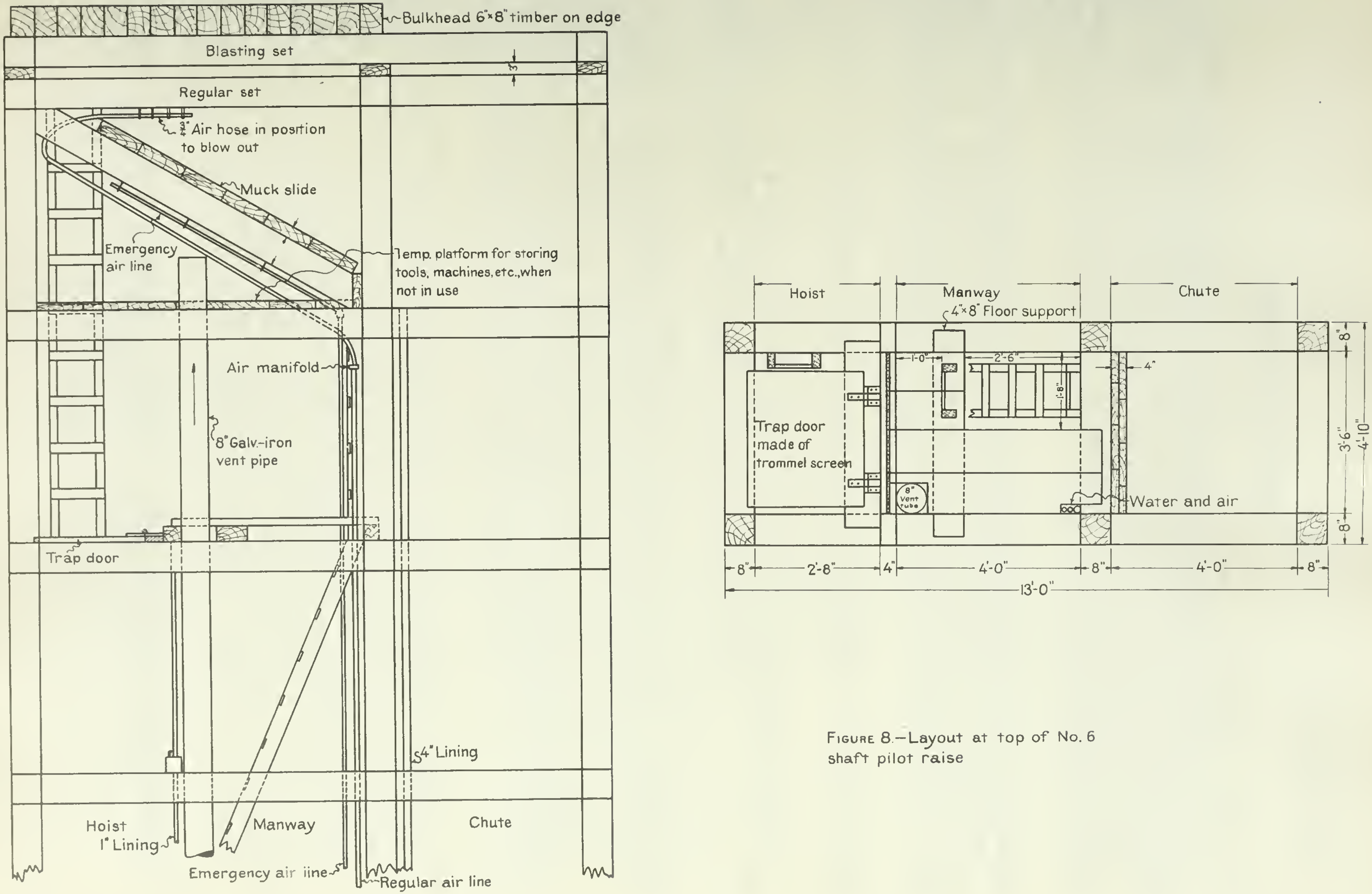


FIGURE 8.—Layout at top of No. 6 shaft pilot raise

EARLY MINING METHODS

Early mining methods in the Morenci district were very simple. After nearly 10 years of mining, during which the Longfellow mine had been worked over an area of roughly 500 by 600 feet, no timber, ore cars, hoists, or power in any form had been used. Open stopes had backs 80 to 100 feet wide supported only by pillars of ore. These pillars had been thinned in times of financial stress, until the mine began to cave over large areas. Entrance to the mine was by means of gently sloping inclines from the hillside, and the broken ore was pushed up the inclines in wheelbarrows.

This was the situation faced by the Arizona Copper Co. in its first years. In addition, the caving had tied up the best of the remaining rich ore in the Longfellow mine. Square-set stoping now came into general use, as it had been in other Arizona camps for many years. Tunnels were driven to reach the ore at lower levels, and tramming in cars was introduced.

In 1906 it was reported that attempts were being made to introduce caving methods into the district at the Shannon mine and elsewhere.[3]

By 1910 the Metcalf, Morenci, and Coronado mines were being worked by many different methods - open cut, surface and underground glory holes, open stope, cut-and-fill, shrinkage, and overhand and underhand square-sets.

In addition, two caved stope methods were in use, top slicing and sublevel caving. The development work for both methods was the same. Crosscuts were driven through the ore on 30-foot centers. Raises from them at 25-foot intervals were put up to the capping. With the ore body thus defined stoping began. For top slicing a good timber mat was established, and the top of the ore body was leveled by square-setting two or three floors. Then top slicing proceeded downward by what is still the accepted modern practice. Headings were run from the raise to the edge of the ore, and crosscuts were made for the width of the panel. Floors 9 to 11 feet high were mined, retreating to the raise.

In the so-called "block-caving" method a sublevel was first driven in the ore 20 to 35 feet below the top of the ore body. The larger figure applied in ground which broke easily and regularly. The sublevel consisted of untimbered drifts and crosscuts on 20 to 35 foot centers. Each of the rectangular blocks thus laid out was divided into four parts by further drifting and crosscutting. Caving was started by drilling and blasting the pillars between the drifts and crosscuts and at the backs of openings, thus undercutting and weakening a block so that it fell and crushed of its own weight. The broken ore was extracted partly by shoveling from the edge of the caved block into the yet uncaved openings and partly by extraction raises put up under the caved area. When waste appeared drawing stopped.

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3 Woodbridge, Dwight E., "Mining, milling, and smelting in the Clifton-Morenci-Metcalf district": Eng. and Min. Jour., July 21, 1906, pp. 83-103.

In 1917 an inclined top-slicing method was in use in the Coronado mine of the Arizona Copper Co.[4] This method had the advantage of eliminating all shoveling of ore in the stopes (fig. 9). The broken ore was blasted down on the sloping floor of the stope from which it ran into a narrow shrinkage stope at the bottom of the trough. The ore from the shrinkage stope was drawn directly into cars through chutes on the motor haulage level. As a result of the substitution of inclined top slicing for flat top slicing, the tons of ore mined per man shift in top-slice stopes increased from 4.90 in 1916 to 11.20 in 1917. The total cost of labor and material decreased from $1.06 to $0.75 during the same period.

A variation of the same method of inclined top slicing was adopted in the Humboldt mine at Morenci in 1918.[5] At this mine the development work consisted of running sublevels at 55-foot vertical intervals and extending raises from the sublevels to the stopes. Each sublevel had a central drift through the ore body, with crosscuts at right angles to it at 50 or 60-foot intervals. From the latter, untimbered raises not over 4 feet in diameter were put up every 15 feet. These lines of raises formed the center lines of the individual slices. In stoping, an inclined heading was driven 44 feet above the sublevel, starting at one end of the line of raises. This heading was timbered with sets 11 feet high and 2½ feet apart. As soon as the heading had gone far enough to intersect four raises stoping was begun. The ground was taken out in panels 10 feet wide and 50 or 60 feet long corresponding to the distance between drifts on the sublevel. The floor of the panel was inclined 37° up on either side of the center heading, and the floor of the heading was funneled down to raises, so that ore blasted from the faces of the panels would run into one of the raises without any handling. When the heading had advanced to open another raise, which completed the panel, the timber was blasted and another started. Posts in the panels were 8-inch round timber, 10 feet long, on 4-foot centers up the incline and 5-foot centers parallel to the heading. These posts were not set normal to the floor of the panel but inclined toward the center heading at an angle of 16½ degrees from the vertical. Flooring consisted of 2 by 12 inch planks laid upon sills of round timber. The sills were so placed as to be readily picked up by the posts of the next lower slice. The ore was drawn from chutes on the sublevel and hand-trammed to motor-haulage pockets. The substitution of inclined top slicing for flat top slicing resulted in increasing the tons mined per man shift from 5.4 in 1917 to 8.8 in 1919. The timber consumption was 7.9 board feet per ton with flat top slicing and was 9.0 board feet with inclined slicing. The total cost showed a reduction of 15 per cent in favor of the inclined method.

The next development at Morenci was a modern caving method--"The Morenci timbered slide caving system." From 1923 to 1926 this method was used for mining a large part of the Morenci ore.

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4 Scotland, P. B., "The Coronado top-slicing method": Eng. and Min. Jour., April 7, 1917, pp. 103-561.
Scott, W. G., "Incline top-slicing method": Trans. Am. Inst. Min. Eng., 1918, pp. 59-305.

5 Hodgson, J. P., and Kiddie, John, "The incline slicing method as applied to large ore bodies": Eng. and Min. Jour., May 27, 1922, pp. 113-914.

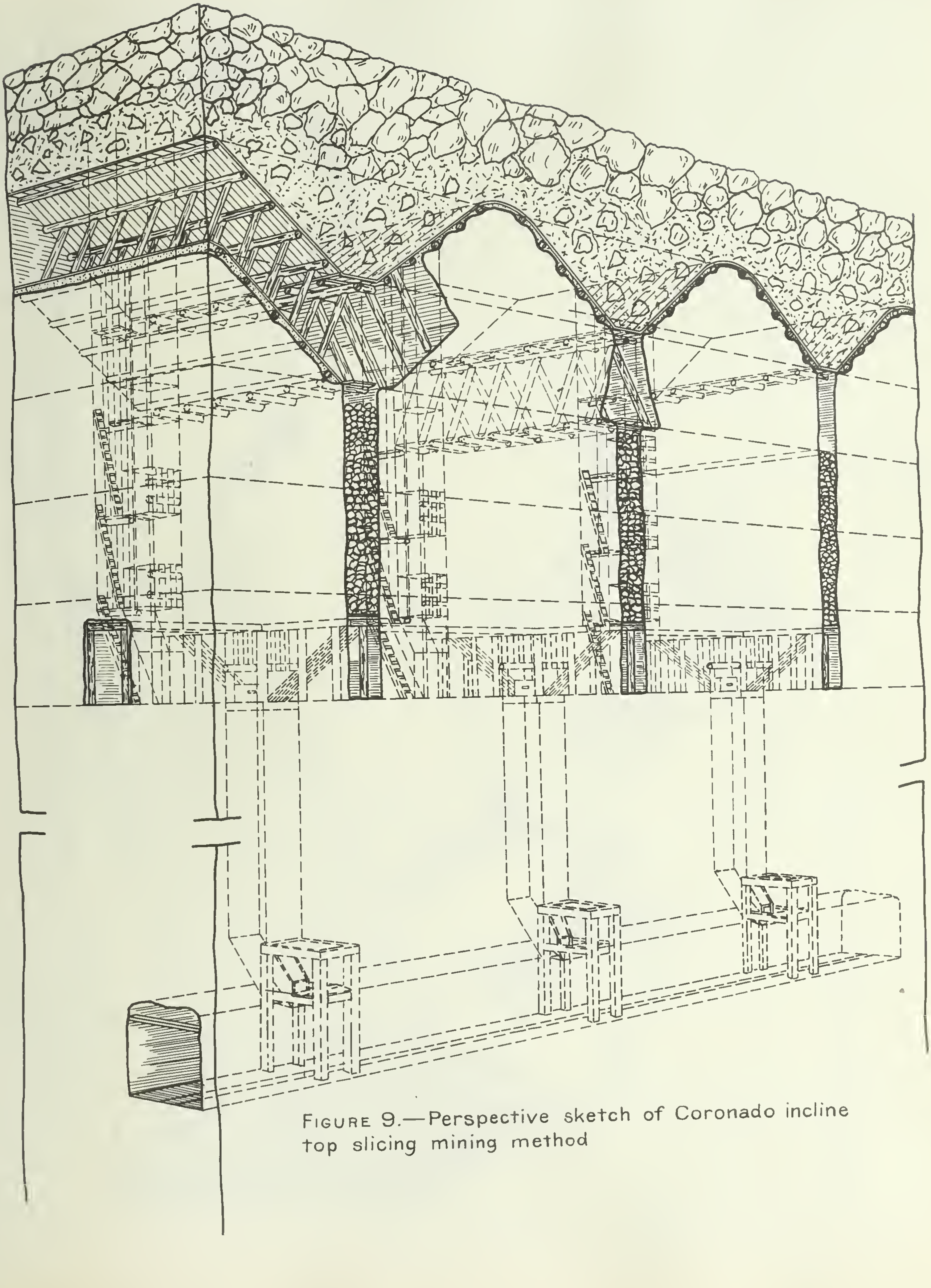


Figure 9.—Perspective sketch of Coronado incline top slicing mining method

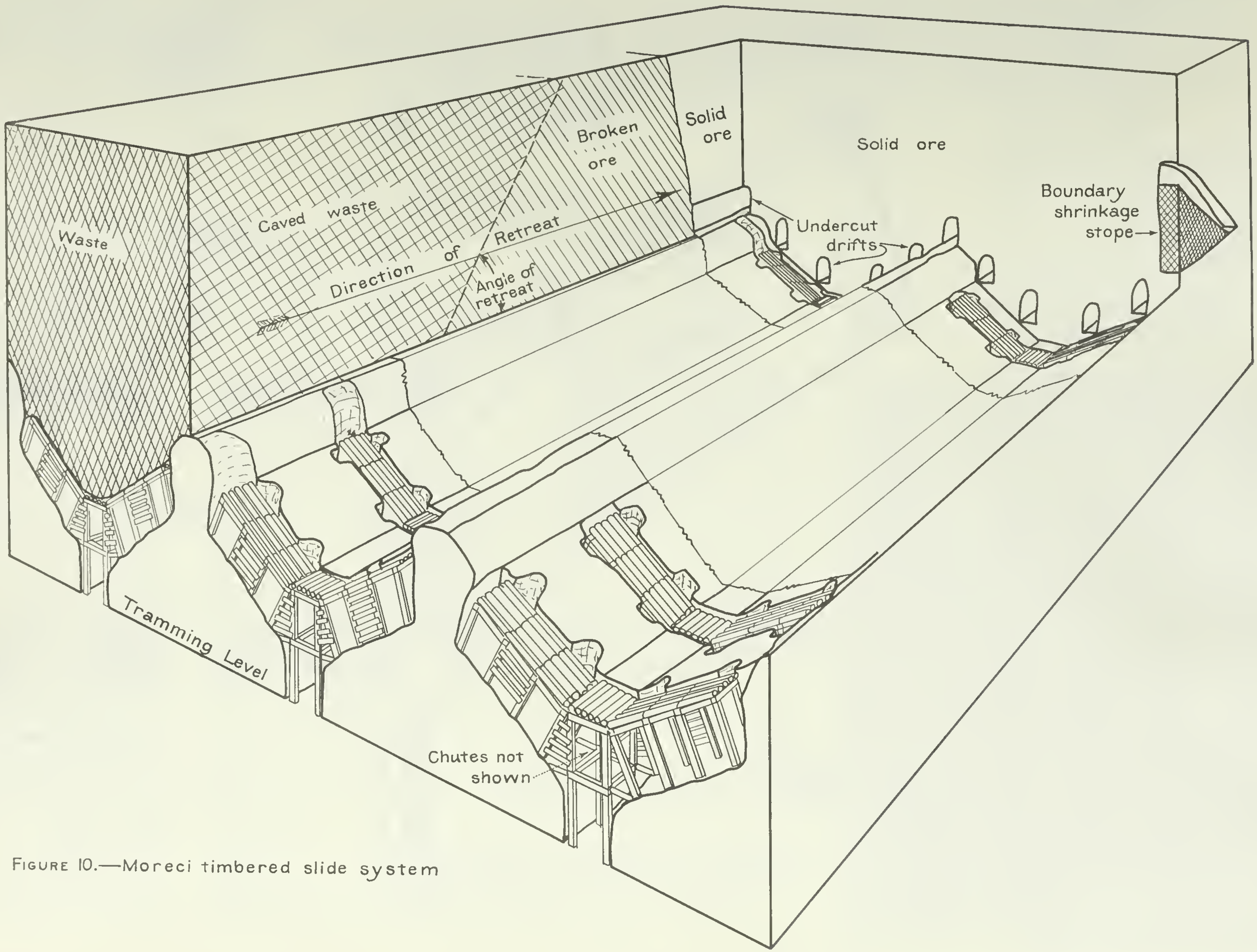
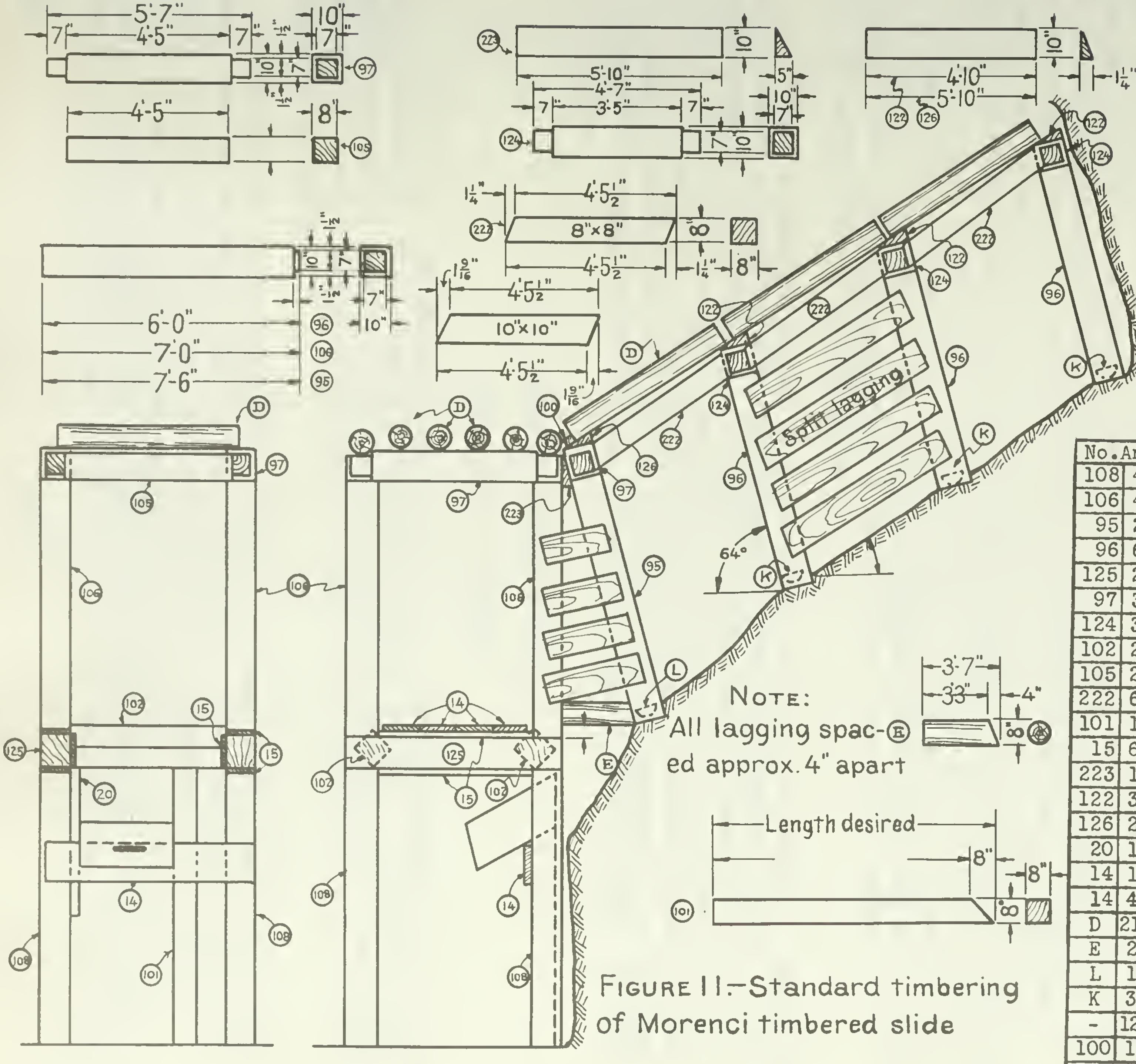


Figure 10.—Moreci timbered slide system



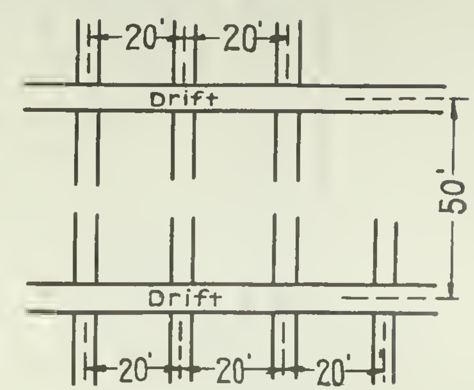


FIGURE 11.—Standard timbering of Morenci timbered slide

TIMBER SCHEDULE

No.	Amt.	Name	Dimension	Description	Bo. Ft.
108	4	Post	10x10x7-6	Square Ends	250.0
106	4	Post	10x10x7-0	See Detail	233.3
95	2	Post	10x10x7-6	See Detail	125.0
96	6	Post	10x10x6-0	See Detail	300.0
125	2	Cap	10x10x5-10	Square Ends	97.2
97	3	Cap	10x10x5-7	See Detail	139.5
124	3	Cap	10x10x4-7	See Detail	114.6
102	2	Brace	10x10x4-2	Square Ends	69.4
105	2	Brace	8 x 8x4-5	Square Ends	47.0
222	6	Brace	8x8x4-6¾	See Detail	131.8
101	1	Post	8x8x L.D.	See Detail	40.2
15	6	Scab	2x10x4-2	Square Ends	41.4
223	1	Scab	3x10x5-10	See Detail	24.3
122	3	Scab	1¼x10x4-10	See Detail	42.2
126	2	Scab	1¼x10x3-10	See Detail	31.5
20	1	Scab	3x10x4-0	Square Ends	10.0
14	1	Scab	2x12x5-10	Square Ends	11.6
14	4	Plank	2x12x5-10	Square Ends	46.6
D	21	Lags	8"rndx5-0	Square Ends	439.7
E	2	Brace	8"rnd.x3-7	See Detail	16.7
L	1	Brace	Split-4-2	Square Ends	4.9
K	3	Brace	Split-3-2	Square Ends	11.2
-	12	Split Lags 5' long		----	64.3
100	1	Scab	2x4x5-10	Square Ends	3.9
				Total Board feet	2,291.

In this system of mining a block or panel 150 feet wide is developed by three parallel hand-tramming drifts run on 50-foot centers (fig. 10). In these drifts every fourth drift set carries a pony set on top of it. From each side of the pony set an incline is driven at right angles to the tramming drift below and is sloped upward at an angle of 33°. Pony sets and inclines are timbered (fig. 11). The inclines do not connect with the corresponding inclines from the next tramming drifts but are stopped so as to leave a 10-foot pillar between. This completes the development work proper.

The next step is the first stage of undercutting and consists of driving small untimbered drifts or "dog holes" parallel to the tramming drifts and just above the inclines or slides. These drifts are spaced on 10-foot centers. Where they cross over the inclines, the floor is cut down so that broken ore from driving and undercutting will roll into the slide without shoveling. A shrinkage stope is run on one or both sides of the panel and across the ends. Where the panel is bounded by caved ground this is not necessary. The shrinkage stope varies from 5 to 10 feet in width and is carried within 5 or 10 feet of the top of the ore. It is mined with a stepped back like the back of a rill stope, in order that entrance may be had at the low point from an undercut drift or the end of a timbered incline. This makes it unnecessary to have cribbed raises for entrance to the stope or manways from the level above.

Actual production begins with the second stage of the undercutting process, which consists of blasting down the pillars between the undercut drifts. At the same time holes 8 feet long are drilled and blasted in the backs of the drifts. Caving is started at one end of the panel and progresses to the other end. Undercutting and drawing are controlled so that the "angle of retreat," which is the angle with the horizontal made by the theoretical plane separating ore and waste in the working stope, varies between 50 and 60°, depending upon weight developed in the stope.

PRESENT MINING SYSTEM

Development of Method

Before 1921 the Humboldt ore body had been mined principally by top slicing and square-setting, with a small proportion of drift caving. At the time of the general shutdown in that year the ore was left in an irregular condition, satisfactory for a continuation of the former methods but not convenient for starting production by caving.

During the years from 1915 to 1922 caving practice had been well established, and the principles were better understood. The reduction in operating cost to be expected from a caving method, although accompanied by a moderate reduction in the assay grade of the ore produced, indicated a good net gain in profits. For this reason it was decided in 1922, when production was resumed, to adopt a caving method for Morenci. At that time several mines were being worked

by caving systems which varied considerably in operating details. The method introduced at Morenci, and from which the present Morenci undercut block-caving system has been developed, embodied the features that were believed to be best suited to the conditions there.

The immediate problem upon starting operations was to resume production as soon as possible. In order to do so, existing development and stope-preparation work was made use of, although it was designed for different mining methods. Various ingenious methods were improvised to take advantage of local conditions; thus the Morenci timbered slide was developed, which is still preferable in certain ground for lifts of less than 100 feet. For the larger blocks, modifications of several caving systems, standardized in some of the western mines, were introduced.

Principles of Mining by the Undercut Block Caving Method

Extracting ore by caving consists of two operations: (1) Undercutting, and (2) drawing off the ore through openings uniformly spaced horizontally below the caving block. By undercutting is meant the blasting and partial or complete removal of a layer of ore across the base of the column to be mined, so as to permit the ore above to cave and break up by gravity. In some districts the ore has at times been broken by vertical shrinkage rooms with pillars between.

The method of breaking up a layer of ore sufficiently thick to cause satisfactory caving is a matter of convenience or economy. For this reason caving practice is not uniform at different mines.

Undercutting is supplemented by breaking loose the caving block from surrounding rock or ore by cutting or weakening it along its boundaries, so as to assist the caving action and confine it to the block mined.

For perfect drawing the draw points should be closely and regularly spaced; but a compromise must be made between close spacing, which increases ore recovery and reduces dilution, and wider spacing, with resulting economy in preparation costs and in operating repairs. The character of the ground controls draw practice, which varies in details but not in theory.

Dilution is caused by the irregular movement of ore and capping toward the drawing points with the formation of pipes of waste which may reach a raise far in advance of the top boundary of the ore. Dilution may also be caused by the general infiltration of fine capping down through coarsely broken ore. In all caving, moreover, there is a gradual mixing of ore and capping as the ore is drawn down. If properly drawn a large part of the ore comes to the chutes clean and before appreciable dilution occurs. From that point the proportion of waste increases and that of ore decreases.

The end point of drawing is set by the value of the ore and the profit per ton or per year at that content of copper yielding the best financial returns. If the plant capacity is large, drawing may continue until near the point of no profit.

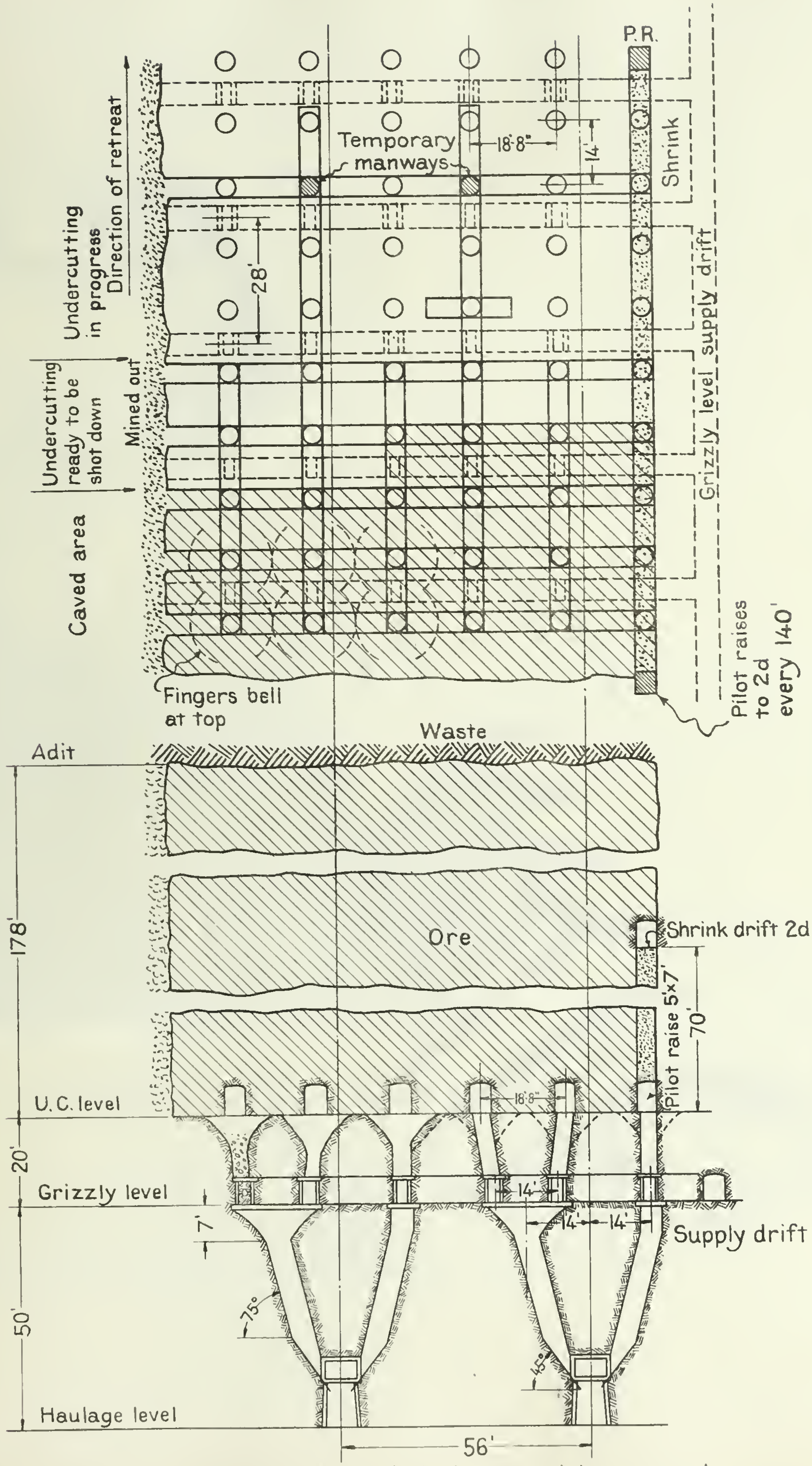


FIGURE 12.—Standard Morenci block cave mining method

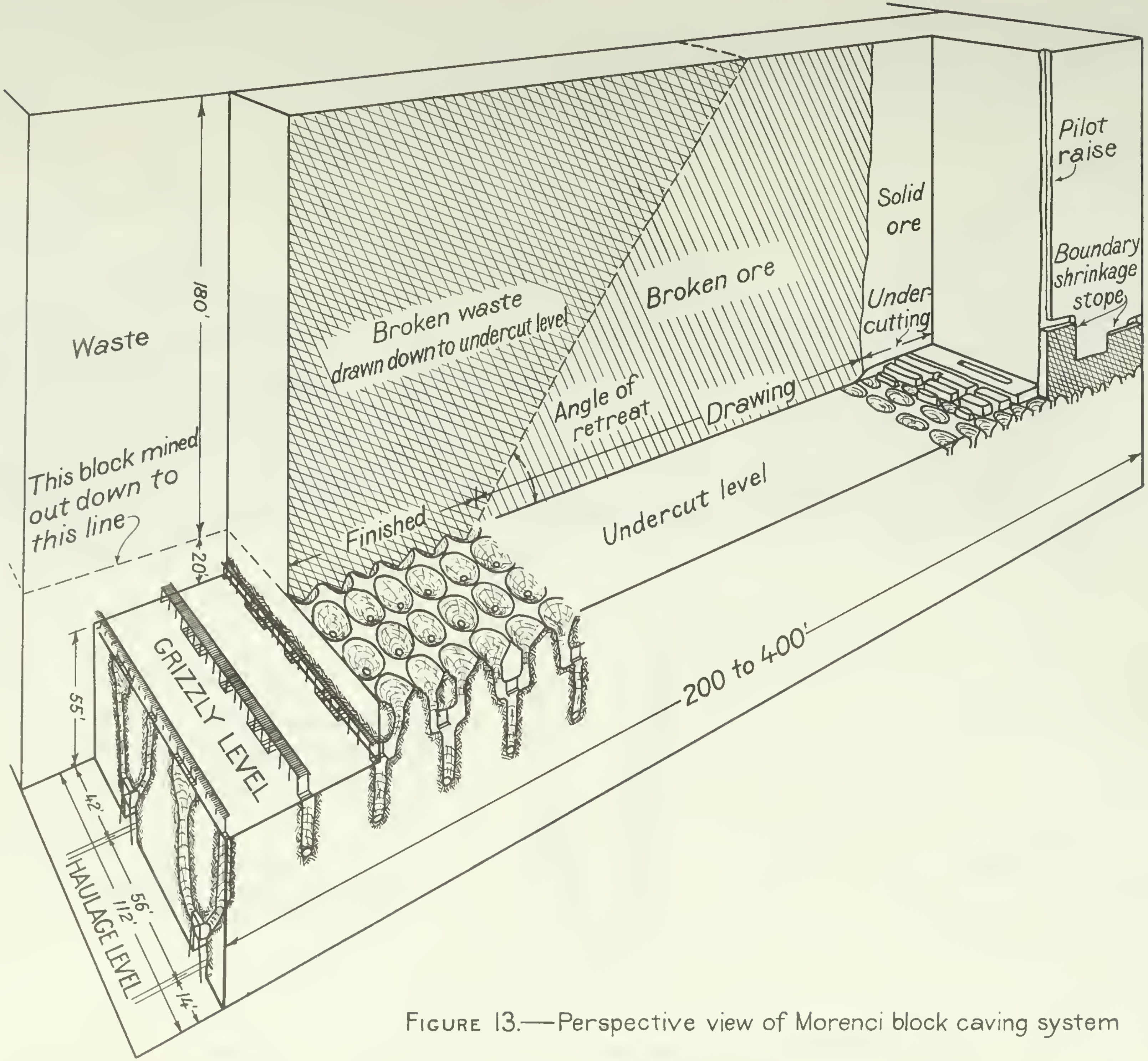


Figure 13.—Perspective view of Morenci block caving system

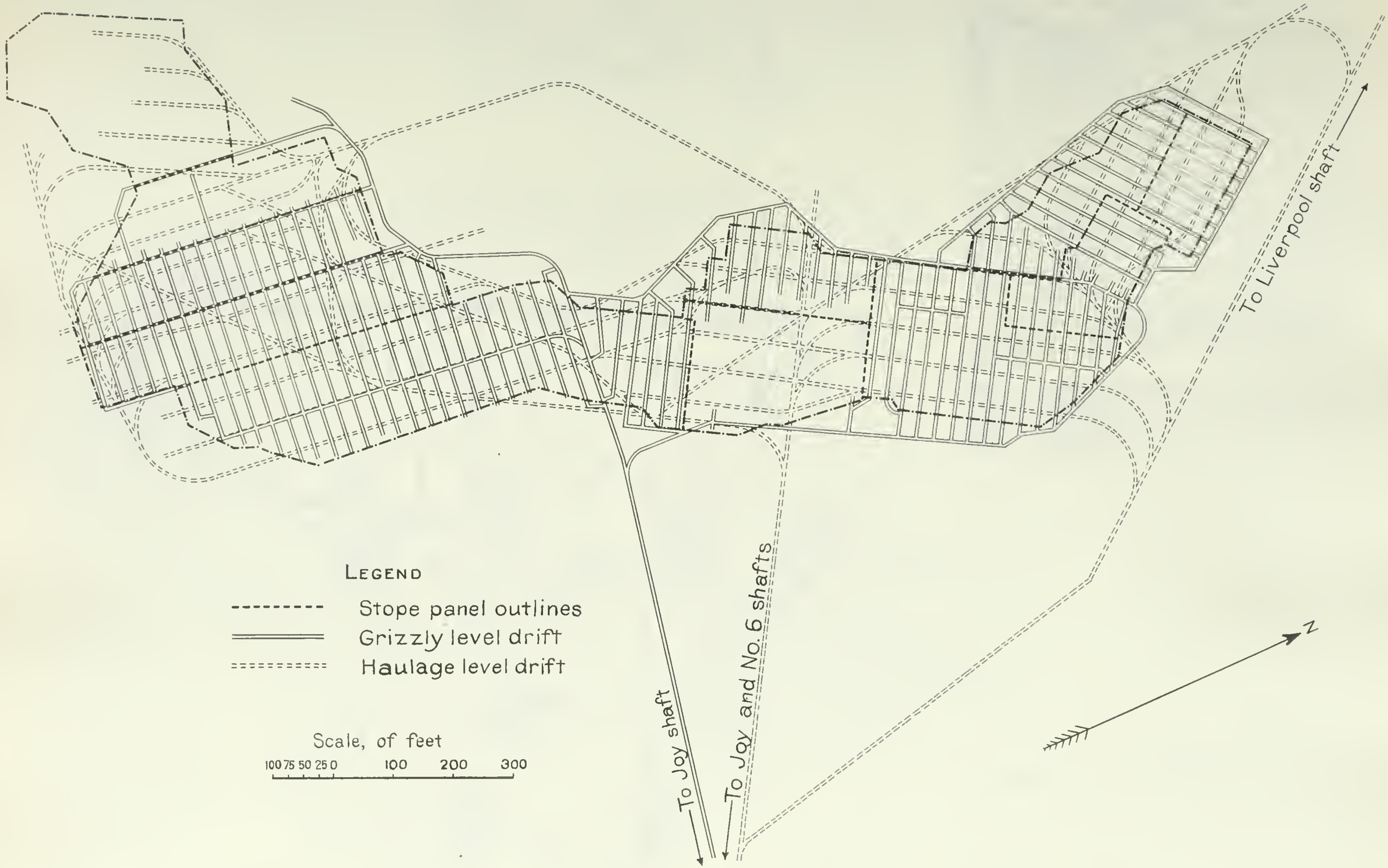
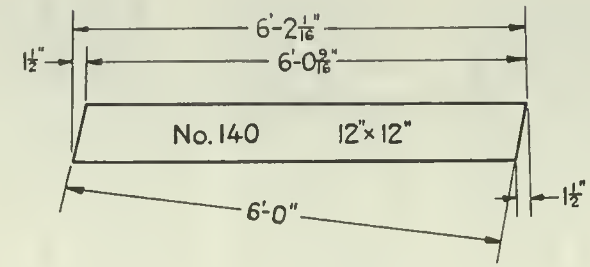


FIGURE 14.—Plan of grizzly and haulage levels, Humboldt mine



No.	Amt.	DESCRIPTION
321	8	12x12x3-6 Sq.Ends (2 invisible underpieces)
324	6	12x12x4-0 " "
322	12	12x12x5-0 " "
141	4	12x12x5-6 " "
68	8	12x12x6-0 " "
140	8	12x12x6-2-1/16 Beveled, See Detail
323	2	12x12x8-0 Sq. Ends
114	8	12x12x14-0 Sq. Ends
103	8	10x10x3-6 Sq. Ends
345	8	3x12x20-15/16 For 50 Rails
30	12	3x12x5-6 Sq. Ends
212	4	3x12x5-0 " "
12	4	2x12x12 Sq. Ends
16	8	2x12x1-9 " "
273	4	2x12x2-6 " "
29	4	2x12x3-6 " "
31	4	2x12x4-0 " "

Below are listed pieces not shown on this drawing but which may be required in abnormal conditions to substitute for certain pieces listed in above timber schedule.

No.	Amt.	DESCRIPTION
344	-	10x10x5'-0" Sq. Ends
113	-	10x10x5'-6" " "
57	-	12x12x12'-0" " "
268	-	12x12x7'-0" " "
325	-	12x12x10'-0" " "

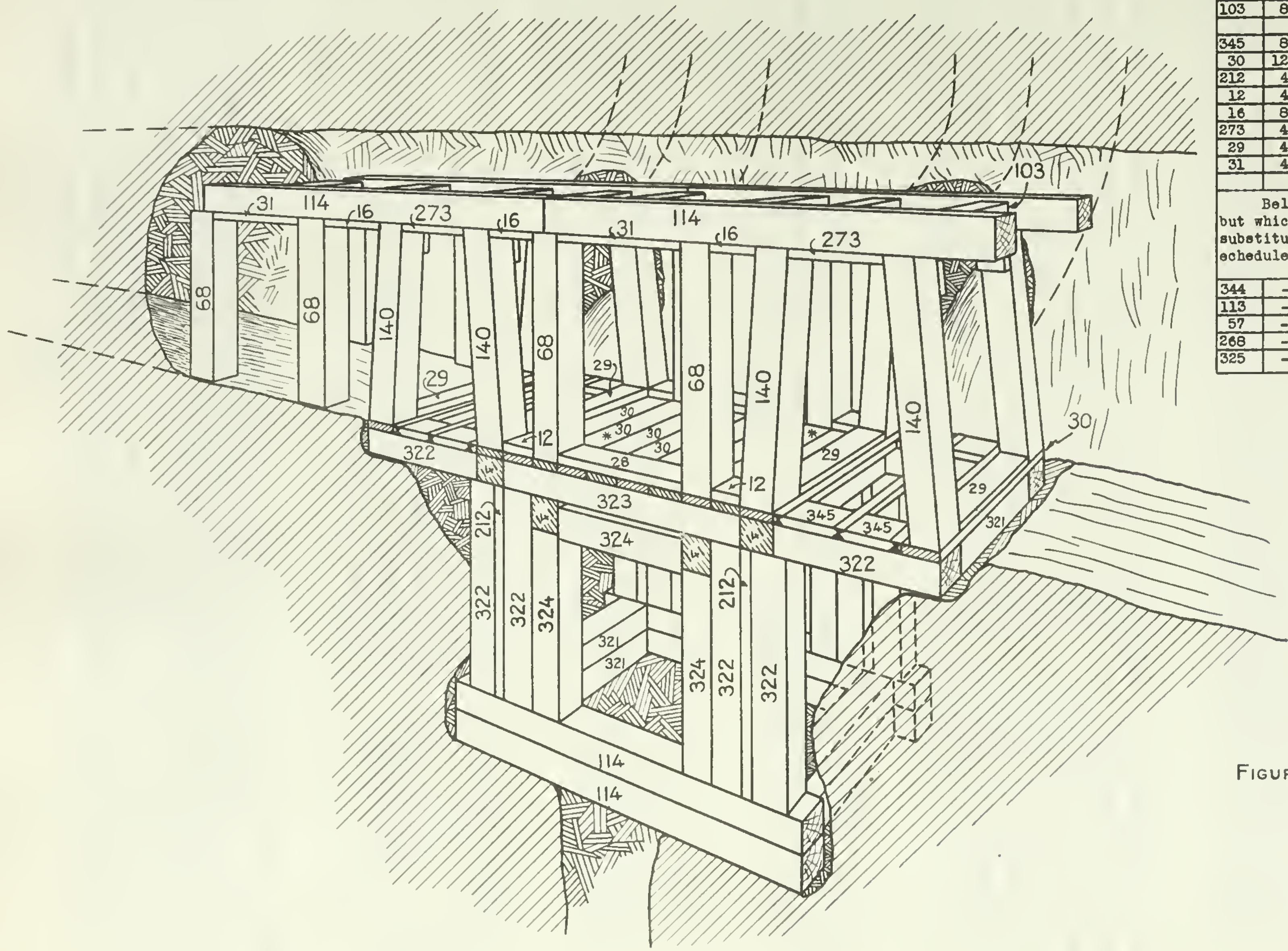


FIGURE 15.—Grizzly station

If not, to obtain adequate profits it must be stopped soon after dilution appears. The system is elastic in that by the sacrifice, for example, of 15 or 20 per cent of the ore its grade can be maintained at very nearly its original metal content.

Caving is characterized by intensive production from small areas and the repetition of a number of simple operations, which leads to the thorough study and complete standardizing of nearly all operations.

Stoping System

The Morenci caving method uses an undercutting level and a grizzly level 20 feet below it. The latter is connected by modified branch raises with a haulage level 50 feet lower. The raises carry the ore passed through the grizzlies to the haulage chutes (figs. 12 and 13).

For reasons of economy and speed in starting production the haulage level already established and in use when caving operations began was extended to gather the ore from the mining area and to deliver it to the shaft. A grizzly level was driven only 50 feet above the haulage level to reach as much ore as possible and still have reasonable storage capacity in the haulage raises. It was connected with the Joy shaft to serve as a main line of communication for men and supplies to the mining area. By this arrangement, haulage on the level below was relieved of practically all interference from the passage of men and supplies.

The elevation of the grizzly level determined the height of draw in the first lift. The ore extended upward to irregular heights above the grizzly level. Its upper limit was the assay boundary between the ore and capping or occasionally the bases of old square-set or top slice stopes. Only incomplete records were available of the ore left about the old stopes.

For mining, the ore body is divided into stoping panels 112 feet wide, which extend more or less on the strike of the ore from one limit to the other. As mining proceeds from one end of the panel it can be followed by another stoping operation in an adjoining parallel panel after enough time has elapsed to allow the caved waste capping to settle in the finished stope (fig. 14).

Each panel delivers its ore to two haulage drifts, 56 feet apart, which run beneath and parallel with the panel. Chute raises from the haulage drifts to the grizzly drifts are driven from the former at 28-foot intervals. The grizzly drifts are driven at right angles to the haulage drifts and across the stope panels. They are 28 feet apart also, and each is directly over and connects with a line of raises from the haulage chutes.

As originally laid out, the grizzlies were set in the drifts 14 feet apart. At present they are symmetrically but unevenly spaced to suit the finger raises. The new arrangement brings the centers of certain pairs of grizzlies 14 feet apart, in which case the top of the haulage raise is widened along the grizzly drift by cutting a slot below the drift to collect the ore from each. This avoids branching the raise, which leaves too weak a pillar between the branches, and has proved to be a stronger and cheaper arrangement (fig. 15).

Two short finger raises are connected with the grizzlies by openings 4 by 6 feet in section cut in the sides of the drifts. On the undercut level they are belled out until they meet. Below this they are widened as much as is safe in order to permit large bowlders to be drawn well down for convenience in breaking.

After the necessary finger raises are driven shrinkage stopes 6 feet wide are carried up on the block boundaries high enough to cut the ore free from adjoining ground and to guide the line of shearing to the top of the ore in the desired plane. The excess of ore broken in shrinking is drawn out through the finger raises.

The shrinkage stopes are started by first driving pilot raises 140 feet apart. They connect with an old intermediate mine level which is situated at a convenient height, 90 feet above the grizzlies. These connections serve to ventilate the pilot raises and shrinkage stopes and also are used as entries for men and supplies.

The shrinkage stopes in soft ground are usually carried up 35 feet. At this elevation it has generally been found possible to leave intact sections 50 to 60 feet in length, situated midway between the pilot raises, and to continue shrinking upward only in sections 40 to 50 feet on each side of the pilot raises. This results in a saw-tooth arrangement of broken and unbroken ground. These shrinkage sections reach the elevation of the intermediate level, 70 feet above the undercut, and if in the opinion of the operating staff it is necessary to weaken the boundary still further they may be driven higher

In beginning the undercut, which follows the boundary shrinkage stopes, one or two drifts on the undercut level are run lengthwise with the panel across several grizzly lines for convenient access to the undercutting drifts. Undercutting drifts 4 by 6 feet in section, locally termed "dog holes," connect the tops of finger raises both laterally and longitudinally, thus forming a gridiron of drifts and leaving rectangular pillars between, about 10 by 14 feet in plan. Certain advance fingers are designed for handling supplies for the undercut section and for ladderways from the grizzly level, thus insuring a safe horizontal retreat for the men on the undercut level.

The checkerboard is developed, beginning at the area already caved, by connecting one or two rows of fingers across the panel and proceeding in the direction of the stope ret

The backs of all "dog holes" are drilled to a depth of 6 feet in fan-shaped rings of stoper holes at 4-foot intervals. These holes are fired simultaneously with the pillar shots. The extra cut assists in starting the caving action and with the open finger raises provides room for the expansion of the broken ore.

The pillars are usually blasted down 2 or 3 at a time, beginning in the heaviest ground and progressing across the stope. Blasting is done with No. 8 instantaneous electric detonators, which have eliminated difficulties arising from cut-out holes as well as the hazards from loose powder in the ore drawn from the stope.

The advantages of the checkerboard system of undercut are: (1) The safety of the workmen who work in low drifts. There is no danger of drilling into a missed hole, for the second half of a pillar is drilled before the first half is shot. (2) The ventilation is good. Fresh air is drawn from the grizzly level through open fingers and is carried up through broken ground in the boundary shrinks to a primary exhaust air course on the intermediate supply level. (3) The method is elastic since the heavy ground may be shot out first, regardless of its location in the panel. (4) Immediate inspection of results is made possible by shooting only a small number of pillars at one time.

In opening a new panel 112 feet wide it is necessary to undercut through a length varying from 84 to 196 feet to break up arches or cantilevers and to start caving freely, even though the new panel may lie against the caved waste filling in a completed section.

The sequence of preparatory operations, based mainly on convenience in disposing of the ore broken in stope preparation, is as follows:

(1) Haulage drifts.
(2) Haulage raises.
(3) Grizzly drifts (a service drift on this level may be driven in advance of haulage raises).
(4) Grizzlies.
(5) Finger raises.
(6) Shrinkage stopes.
(7) Undercutting.

All these operations are carried on at the same time, each process being sufficiently in advance of that following it to avoid interference and provide convenient means for getting the ore to the haulage cars through haulage and finger raises.

In mining a block of ore 150 feet high, including the necessary development work and boundary shrinkage stopes on one side and two ends of the block, the amount of ore actually drilled and blasted is less than 10 per cent of the total ore removed.

After undercutting, drawing begins; the work is done slowly at first until the ore starts to cave freely, and afterward at the rate that best suits its nature. The fact that the ore is drawn from the stope and worked through the grizzly at the same place permits one man to perform both operations.

Electric firing is used for block-holing bowlders on grizzlies and starting hung-up drawing raises for safety and for eliminating smoke from fuse. The entire active portion of the panel is wired in parallel with a permanent blasting circuit. There are four breaks in this circuit, as follows:

(1) An open clip is installed in a drift set adjacent to each grizzly. The lead wires are attached to this clip.

(2) A similar open clip is placed at the entrance to each grizzly line.

(3) There is an interrupter switch in the supply drift at a safe distance from the last grizzly line.

(4) The firing is done by means of a firing switch at the exit of the stope. As an additional safeguard the wire used to close the open clip at the entrance to each grizzly line is attached to a chain hanging on the opposite side of the grizzly drift. When the wire is in place in the clip the chain from which a blasting danger sign is suspended must be drawn across the grizzly drift.

By the use of electric firing the chute-tapper is able to place his bombs in the most favorable positions in the hung-up fingers, can remove the plank covering over the grizzlies as he retreats, is not required to work in a smoky atmosphere as when using fuse, and has ample time for all operations, so that he is not hurried and does not have to work under strain.

Morenci practice is dictated by the existence of a large proportion of hard, coarsely-breaking ore which has developed three innovations: (1) Drawing through large openings in the sides of the grizzly drifts instead of through timbered chutes; (2) using grizzlies in the stopes with bars spaced 16 inches apart instead of the customary 10 or 12 inches; (3) using one man to draw the ore and also work it through the grizzly.

So much coarse rock occurs in every section that ore can not be drawn through small chute doors satisfactorily. Openings 4 by 6 feet in section are therefore cut in the sides of the grizzly drifts, which connect with the finger raises. The ore flows through these large openings to the grizzlies where it is broken up by sledging or block-holing. At the grizzlies there is enough room to work and to get away if a surge of ore occurs. Wide spacing of grizzly bars reduces sledging and block-holing, although it then becomes necessary to change haulage, hoisting, and coarse-crushing equipment to accommodate large bowlders. The advantage of the wide spacing is reflected in chute-tapping efficiency, which has increased to its present figure of 120 tons per man shift from an average of 37 tons per man shift with 10-inch grizzlies. As a protection against falling through widely-spaced grizzlies the chute tapper is provided with a safety belt which he always wears while at work on the grizzly. Contrary to the popular impression before this innovation was tried, the belt does not interfere with the output of the workman. When not actively in service all grizzlies are covered with two 10-inch planks. Handholds of substantial chain are installed on both sides of each grizzly.

Previous to the introduction of the wide grizzlies it was occasionally impossible to put the ore through as fast as stope conditions dictated. Drawing can now be increased to a rate of 1,200 tons per day from an area of 10,000 square feet whenever it may be found desirable to do so; this means caving at a rate of $1\frac{1}{2}$ feet vertically per day.

In the active portion of a producing panel some ore must be drawn from each finger every day to prevent local packing. The minimum draw in areas which are being held back for purposes of stope control is 12 tons per finger.

Each process in the preparation for drawing must be designed to conform with the factors governing the efficiency of that operation.

(1) The ore must be completely undercut. If even a small area remains unbroken it acts as a pillar, by which excessive pressure is transmitted from the broken ore to the grizzly level. The layer of ore broken during undercutting must be thick enough to allow caving to begin.

(2) Enough ground must be cut through in the boundary shrinks to permit the blocks to begin caving without delay after undercutting, but not enough to cause the whole block to collapse at once. The continuous stope cut out for the lower 35 feet of the block boundary assists the caving. Leaving part of the ground in place on the boundary above prevents caving too fast, and in large masses.

Morenci ore varies so much that no constant percentage of the area on the boundaries can be used to decide how much shrinkage stoping is to be done. That must be left to the judgment of the operator. It is better to cut out too much, even at the risk of a sudden collapse, than too little and have the block hang up indefinitely. Moreover, sections of unbroken ground on the stope boundaries should not be so great that the line of shearing may diverge from the desired plane.

(3) Drawing points are subjected to great pressure. As far as possible they should be protected from weight in order to permit continuous drawing and to avoid repairs which would interrupt drawing and increase the cost of maintenance.

Weight is resisted most efficiently by leaving as much unbroken ground as possible about the grizzly drifts to act as pillars. This can be accomplished by keeping the size of the grizzly drifts small and by cutting down the number of finger raises that are driven through it. Wide spacing of the fingers is limited by the requirements of good drawing, which prescribe spacing them as closely as possible. The result is a compromise spacing such as will yield the best returns.

Pressure on the grizzly drifts is affected by the rate of drawing. If it is too slow, weight on the grizzly drifts will gradually accumulate, while rapid drawing relieves that pressure.

(4) The grizzly bar spacings limiting the size of bowlders that pass through them should be as wide as the subsequent operations of hoisting, haulage, etc., will permit. When the ore to be handled is naturally coarse the spacings should be planned to handle large bowlders conveniently. Chute-tapping labor is thus reduced and the speed of drawing increased.

(5) Haulage raises should have sufficient storage capacity to make the operations of ore-drawing and haulage independent of each other.

The tendency in stoping operations at Morenci, as at other mines in the Southwest, is toward higher lifts, which reduce preparatory or development costs. In 1928 the average stoping lift was 164 feet, while on the next lower stoping horizon this will increase to 270 feet.

An increase in the height of the ore column above 250 feet reduces the cost of stoping very little. It increases the total length of time required for the ore to reach the mill after being broken in the stope. This delay in drawing may be detrimental to certain ores that oxidize rapidly for concentration by gravity or flotation. There may be a slight filming of the sulphide surfaces that interferes with flotation without an appreciable increase in the amount of acid-soluble copper.

Method of Controlling the Draw

When a new stope is ready for production, the plans and sections for it are assembled by the stope-control department. The plan is a special map of the stope showing each finger and corresponding haulage raise. On the plan the line of fingers is numbered in one direction to show the page number on the section; in the other direction the numbers designate the grizzly lines, as shown in Figure 16. Thus "4-96" is used to designate the first finger on the south side of the bottom row. This method identifies the finger on the office records and also gives its location underground; several fingers branch from one raise. After the plan is completed the tonnage tributary to each finger is calculated from the ore outlines shown on the assay maps. These tonnages are recorded on the finger map and are adjusted to agree with the ore reserves. From these tonnages, longitudinal sections are made. Each page of sections represents a line of fingers (fig. 16). These sections are based on broken ore volumes as distinguished from rock in place. The increase in volume is termed the swell. The ore in place runs 12 cubic feet to the ton while the broken rock is considered to be 20 cubic feet to the ton, so that each finger in the section is increased 40 per cent to allow for the breaking up of the rock. These plans and sections are made on a scale of 1 inch to 20 feet. In the present stopes, where the fingers are spaced on 14-foot centers in one direction and 18 2/3-foot centers in the other direction, the tonnage scale runs 13.07 tons to the foot. The tonnage is posted on the sections in different colors, according to the month the ore was drawn. The stope is controlled primarily from these sections. They show (1) the angle of retreat; (2) when a finger is being pulled too fast; (3) when a finger is not being pulled at all; and (4) when the stope as a whole is being pulled too slowly or too rapidly.

If a pipe of cap rock reaches a draw point in advance of the upper boundary of the ore body, the finger is sealed and ore is drawn from the surrounding raises until the waste pipe is broken. Close spacing of draw points facilitates the breaking up of pipes of waste; if the draw points are too far apart they do not assist each other.

The proper rate of draw is dependent on the rate at which the unbroken ore caves. If the ore is drawn too rapidly too large an open space will appear between the broken and unbroken ore. In such case the ore is likely to break in large masses. If it is drawn too slowly the swell of the broken ore will partly support the arch above and delay caving.

After caving reaches the top of the ore there appears to be no limit of drawing speed other than the ability to put the ore through the grizzlies and preserve a proper relative movement of the ore and waste capping to the chutes. If a heavy spot appears in the stope, more rapid drawing at that area relieves pressure on the grizzly level.

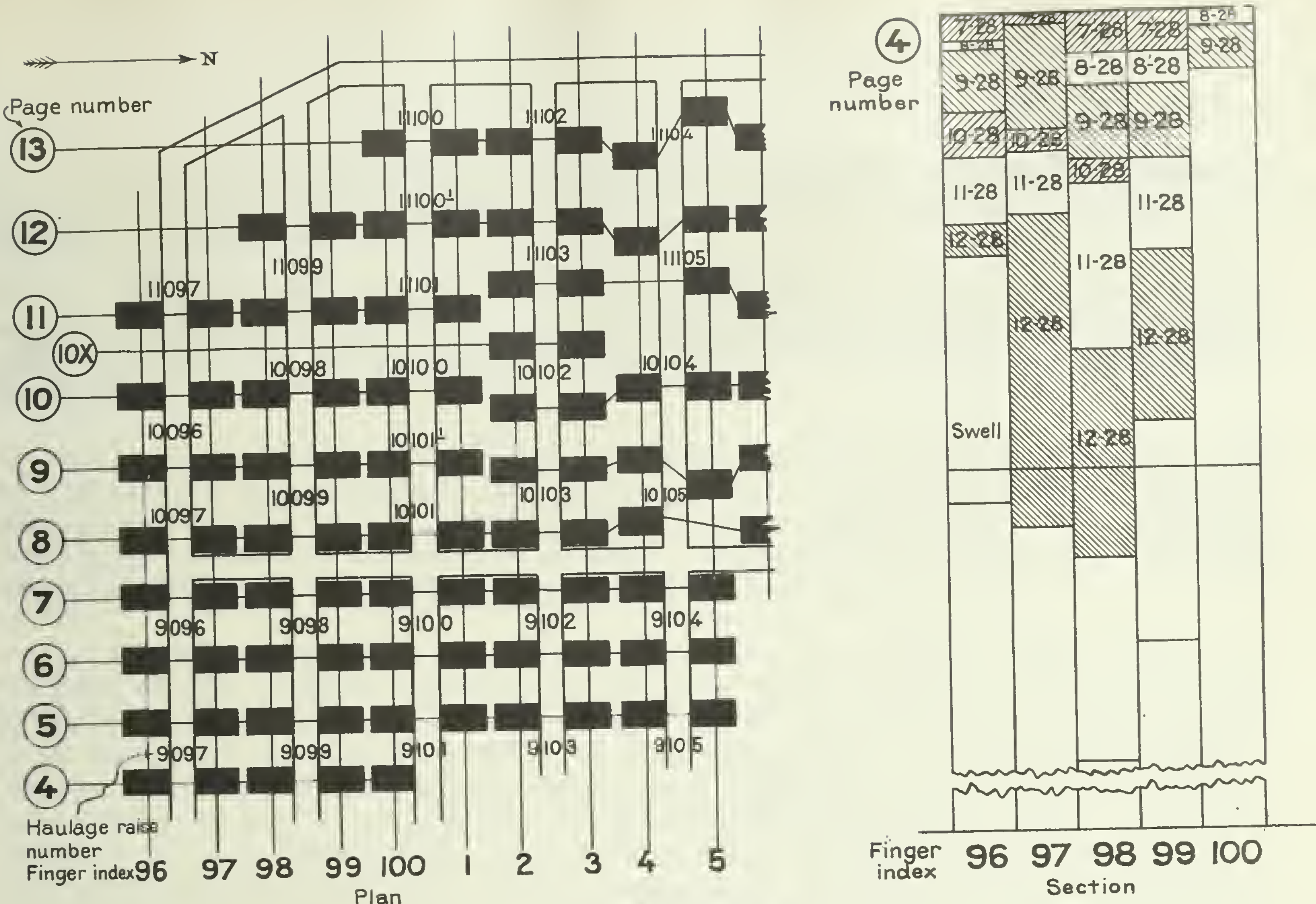


FIGURE 16.—Stope control

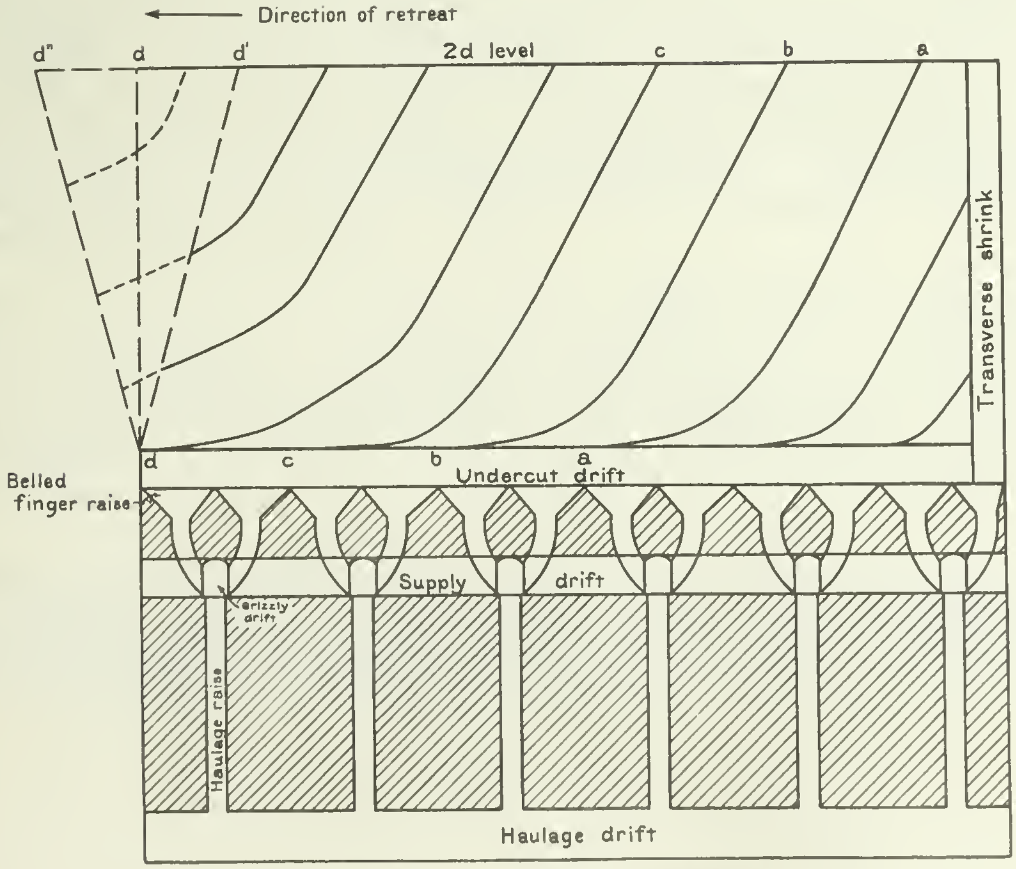


FIGURE 17.—Typical section showing progressive stages of caving. Looking at right angle to line of retreat

When the ore in a section is nearly all drawn off, the rate of drawing is decreased to give time for sampling doubtful chutes and obtaining the maximum recovery of clean ore.

During the initial stages of drawing the angle of retreat is 60°. As the stope is extended the angle is decreased to approximately 50° or to even a smaller angle if weight does not interfere. This angle is maintained to the completion of the stope.

As the undercutting advances, a certain tonnage of the most recently undercut ore is held back undrawn in the reserve column. The swell in this section is released for drawing at a slow rate. By this means the entire block is broken up more finely in advance of the regular draw. The reserve of broken ore continually varies according to the relative amount of ore undercut and drawn.

In each stope and on each shift there is a chute checker whose duty is to see that the ore is drawn according to the draw sheet which is issued to him each day by the control department. He makes a tonnage report for each finger worked during his shift and also takes samples from each finger. He turns in a report from the transportation department showing the number of cars pulled from his stope during the shift. He closes off the fingers marked "waste" and also makes a note of any new fingers that start running waste during his shift and reports this to the office. The chute checker keeps track of the haulage chutes that are full and delivers a list of these to the transportation crew at regular intervals. This list is dropped from the grizzly level to the haulage level by way of a 3-inch pipe that runs through an old chute in an adjacent section of each stope.

When the reports are received in the office the cars are apportioned according to the fingers worked. The tonnages are then posted on the finger sections and new draw sheets made out. The draw sheet shows the total number of tons released in each finger, the fingers to be closed off, and the maximum daily rate of draw for each finger. The results from the finger samples are posted on a sheet showing the number of cars drawn from that finger during the day. These assays are all averaged together according to their tonnages to give a composite result for the entire stope production for the day.

Ore drawing is an art. The engineer in charge of the stope-control department starts with a knowledge of the quantity, position, and assay grade of the ore in place. From the quantity of ore drawn and its grade, the weight on the drawing section, and the behavior of certain finger raises, he is able to form an idea of what is happening in the mass of broken ore above, how it is moving, and how to plan for its extraction.

The stope-control department must rely on the full support of the mine foreman and his staff. It must be understood, however, that the daily production must be made and the control department in turn must assist the miners. Unless there is entire cooperation something will suffer.

One of the most interesting phases of caving operations is the rock-mechanics of the caving action. There are many theories as to the details of this action which are usually prompted by observations of individual stopes in a particular mining district. The Morenci conception of a normal case is illustrated in the longitudinal section (fig. 17), which is typical of uniform ground. Any major planes or areas of weakness would of course induce different results from those illustrated.

The actual undercutting is delineated in Figure 17. Caving is initiated along a rather flat inclined brow which often approximates a slope of 30°. This steepens against the caved ore to perhaps 60°. With sufficient time interval this brow stabilizes in an almost vertical position at the extreme edge of the undercut. It may (1) project slightly over the caved ore, (2) stand exactly perpendicular, or (3) even extend at a small angle beyond the basal undercut (<u>d</u>', <u>d</u>, <u>d</u>'' in fig. 17).

The rate at which the fragments of ore, locally termed raveling, drop down from the unbroken mass depends upon the tensile, shearing, and crushing strength of the ore. The strength in turn is affected by such physical characteristics as fracturing, faulting, jointing, texture, hardness, chemical composition, and alteration. The actual rate in a vertical distance may vary from 0 to 20 or more feet per day.

This brow probably constitutes a cantilever whose fulcrum is immediately beyond the edge of the undercut along the line of retreat. In certain hard ground at Morenci, to protect the advance stope development from closing in as a result of concentrated weight at this fulcrum, shallow transverse shrinkage stopes were deiven entirely across the stoping panel. In softer ground such shrinks are unnecessary.

When the transverse shrinks are driven, the stope resembles the rectangular blocks, in use elsewhere, that are cut off on all sides and in which the ore is drawn down horizontally. At Morenci the proper angle of retreat is maintained.

To prevent undue weight a slower initial rate of draw at the edge of the undercut towards the line of retreat has proved beneficial. By this treatment the ore is also broken in smaller pieces.

The time element is an important factor in breaking ground fine. Excessive speed in undercutting and drawing, or transverse and boundary shrinks driven too high, will produce coarse-running ore.

A series of boundary shrink drifts with intervening horizontal level pillars gives the proper delay in caving in soft ground, but there are few blocks in Morenci where such drifts can be used. The ground is usually so hard that it bridges over these drifts and all caving action is stopped, unless enough ground is cut out to make the caving positive. In Morenci ground the horizontal pillars must be cut down to such narrow dimensions that this method is not economical.

However, the delayed effect has been obtained by the saw-tooth shrink, as described. The first ore drawn after the actual undercut ore is removed, is usually the coarsest. A grinding action is later established in the higher ore column, which produces finer ore. The weight of the overburden undoubtedly assists this action. In one case at Morenci, the ore in a stope, with a lift of about 150 feet, extended almost to the surface without the usual leached capping. This block produced very coarse ore.

In a wide stope it has been observed at Morenci that the greatest weight on the grizzly level pillars is in the center of the panel. The resulting weight is proportioned similarly to the deflection of a uniformly loaded beam supported at the ends. By narrowing the section from the original 165 feet to the present 112 feet this effect was diminished. It is thought that the side friction of the moving ore along the walls of the stope acts as a retardant.

Dilution.- Owing to uncertainties in tonnage and assay grade of certain blocks in older sections of the mine because of incomplete information, the data on dilution at Morenci are not considered entirely reliable and hence are not included at this time. The ore, breaking very coarse, draws down quite uniformly and has but little tendency to pipe. The result has been exceptionally clean ore with very little dilution.

The method of computing dilution is the same as is used at the Ruth mine of the Nevada Consolidated Copper Co. In this method the capping is assumed to be barren. The percentage of copper extracted as compared to the expectancy equals the percentage of clean ore shipped. The tons of capping shipped can then be calculated. The percentage of capping shipped is the dilution.

UNDERGROUND TRANSPORTATION

About 5,000 tons of ore per day was mined during February, 1929. The ore from the stopes is loaded into 6 or 8 ton cars and pulled by electric locomotives about three-fourths of a mile to No. 6 shaft, where it is hoisted to the mill bins.

The haulage department is operated under separate head; haulage is continuous for 24 hours per day six days per week. The mill operates seven days per week.

Since each "line" or row of grizzlies on the grizzly level feeds the chutes located in two or more haulage drifts, increasing the number of lines producing ore at one time has increased the number of chutes that may be drawn in each haulage drift, thus obviating some switching in the collection of a trainload of ore.

The loop system of haulage is used (fig. 14).

The trains consist of 15 eight-ton cars or 20 six-ton cars. Two haulage crews are used on the main line and two crews in the stoping area. A train can be loaded in about the same time that a round trip can be made to the shaft. Each main-line train makes 9 to 13 trips per shift. A train of 15 cars is usually unloaded in 7 minutes. The full-load speed of the train is 6 miles per hour.

The head brakeman of each train fills out a printed form showing the number of cars pulled from each chute as it is drawn. This report is given to the stope-control department in the engineering office at the close of the day. This record is checked against the chutes reported full by the chute checker. The actual tonnage is allocated to its proper chute by applying a car factor obtained each day by weighing all loaded and empty trains on platforms scales which are situated near the shaft.

Loading at the chutes, switching from chute to chute in collecting a trainload of ore, and dumping at the shaft occupy about three-fourths of the operating train time.

By widening the chute doors from 30 inches to 42 inches and increasing their area, the speed of loading was nearly doubled. Large chute doors are particularly important when there is coarse ore.

HOISTING

Only one class of ore is mined on company account. All of it--about 140,000 tons per month--is hoisted through No. 6 shaft from the 5th level.

The ore is hoisted in two 4.6-ton skips run in balance. The distance from the skip loading station to the dumping position is 512 feet. The average time for a round trip of one skip is 2.0 minutes. The average number of skips hoisted per day including Sundays is 1,250.

Waste from development work is hoisted through the Liverpool shaft. Men and supplies for the lower levels are also handled at this shaft.

The Joy shaft is used for handling men and supplies to the stoping area of the mine.

VENTILATION

The mine is mechanically ventilated by two centrifugal fans that have forward-curved blades, double inlets, and horizontal top discharge. They are operated at 340 r.p.m. by belt drive from 100- hp., 2,000-volt induction motors. The rotors are 5.5 feet in diameter and 5.4 feet wide. The fans are situated at opposite ends of the ore deposit at the portals of adits connected by upcast raises with the producing areas. They operate as non-reversing exhausters. One fan exhausts 89,000 cubic feet per minute and the other 79,000. The fans have separate air returns of high frictional resistance and common intakes of low resistance.

The two lobes of the ore body are separately ventilated because of anticipated difficulty in maintaining connection with a common air return. A fan exactly similar to the two surface fans, installed on the No. 5 level in a by-pass near the Liverpool shaft, is maintained in operating condition for fire emergencies

Long development headings are ventilated by the use of small high-speed blower fans of various types, and canvass tubing. Two fans in a station several hundred feet from the fresh-air intake are used in combination for this purpose. The smaller fan is situated on the fresh-air side of the station and blows a large part of the intake air coming in through the drift to the face of the heading through 12-inch canvas tubing. The larger fan exhausts from the face of the heading and discharges the exhaust air through a 16-inch canvas tubing into the nearest return-air opening. By this arrangement some intake air is short-circuited into the exhaust air but no exhaust air can be returned to the working face.

The mine is cool throughout, both winter and summer. During the winter season it is necessary to avoid producing high-velocity air currents in working zones in order to avoid uncomfortably cold conditions. The rock temperature in the lowest development headings--a drainage tunnel on the No. 18 level 900 feet below the adit level--is, however, 76°, so that the coolness of the workings is due to the shallow depth and lack of any rapid degree of oxidation in the caved and abandoned areas adjacent to working areas.

Air samples show that the quality of the air, as to chemical composition, is good throughout the mine.

The ventilation system is planned to draw dust and foul air out of the mine as directly as possible without carrying it through working places.

DRAINAGE

The only pumping in the present workings of the Morenci Branch is in the bottom or 14th level of the Liverpool shaft. This level has been driven from the Liverpool shaft past the Joy shaft to No. 6 shaft--a total distance of 4,000 feet. As the grade is slightly downhill in the direction of driving from a point 1,000 feet from the Liverpool, water tends to collect and must be forced back to the Liverpool pumps.

The pumps used for this purpose are two 1½-inch centrifugals, driven by 5-hp. direct-current motors. One of these is pumping a distance of 3,000 feet against a 10-foot head. The other handles less from a drift heading which is not advancing at present.

Two electrically-driven triplex pumps are in use at the Liverpool shaft. One takes water from a sump at the 14th level, 725 feet below the collar of the shaft. The other operates from a sump at the bottom of the shaft, 830 feet below the collar. A flow of 50 gallons per minute is being pumped at present from these two points to the surface.

WAGE SYSTEM

For the year 1928, 72 per cent of all labor in the mining department was paid on bonus or contract systems. The other 28 per cent was on day's pay.

Contracts

A standard set of contract prices is in effect throughout the mine. The foremen who let the contracts have copies of the contract schedules. These contract prices cover such work as drifting, raising, and winzing--both driving and timbering--laying track, digging ditches, undercutting and shrinking in stopes, and salvaging mining material. The rates are followed very closely and seldom changed. Unusual conditions are stated on the contract form and authority for changes from the standard must be obtained from the mine superintendent before a contract is let. All measurements are made on the 15th and 30th of each month, and the earnings are computed by the engineering department. All men on contract are guaranteed day's pay at the prevailing wage. The time and class of work done by each man on a contract is recorded by the shift boss.

The manner in which this contract system differs from systems employed at many mines lies in the way in which the proceeds of a contract are shared among the workmen participating. The earnings may then be divided by any one of four methods: (1) An equal division of earnings to all men concerned in the contract; (2) the payment of day's pay rates to all according to their respective day's pay rates, with an equal division of the surplus; (3) payment of day's pay rates to all, then a division of the surplus in proportion to his day's pay rate; (4) straight payment to each man for the work that he does, having separate prices on timbering, mining, mucking, etc. The choice of the method of dividing the proceeds of the contract is left to the discretion of the foreman, who is familiar with the work, its conditions, and the desires of the men.

Bonus

A bonus system is applied to men working in stopes and on transportation crews. In arriving at the bonus rates past daily performances of men employed at various classes of work have been averaged to determine a "base" for each class. This base represents the amount of money that would be paid if a man does an average day's work, and corresponds to a day's pay. This figure divided by the number of tons representing an average day's work is called the "base cost per ton" (or other unit). If a man exceeds an average day's work he is paid one-half his "base cost per ton" for each unit by which he exceeds average day's work.

The base in each working place is subject to change at the beginning of an period if conditions should warrant it.

At the drill-sharpening shop the proposition was made to the men that one-half of any saving in labor effected by a reduction in the force would be divided equally among the men in the shop. This ruling had the effect of raising the quality of the bits turned out because with a higher standard of bit there was less work in the shop and less men were required. The base number of men is subject to change at the discretion of the mine superintendent when any of the operating conditions undergo changes, such as variation in amount of work done in the mine, change in shop practice, change in shop equipment, or change in scale of operations. The drill-shop foreman was not included in this bonus.

The mine shift bosses do not receive a production bonus but do participate in an accident-prevention bonus based on a graduated scale for each 1,000 shifts supervised without an accident.

ACCIDENT PREVENTION

Safety of workmen is considered a major operating problem. The management insists that accident prevention be considered before production or costs. Plans for all work are first considered and approved from the standpoint of safety.

The safety organization consists of a branch safety engineer and a mine safety inspector. Safety inspection committees, consisting of workmen and the safety inspector, make periodical inspections and recommendations for eliminating hazards whether in practices or equipment. The work involved in carrying out these recommendations, when approved by the superintendent, is given precedence over all other operations.

General safety meetings attended by all the workmen and bosses in each section of the mine, are held at regular intervals on company time for the discussion of safer practices.

First aid is taught to all new employees. All employees are encouraged by yearly competitions and prizes to review their first-aid traing.

Two mine rescue teams are kept in regular training and a third team is kept in reserve training.

The mining staff at regular intervals is given special instruction in handling underground fires to prevent loss of life and destruction of property.

COST OF OPERATION

Table 1.- Summary of costs in units of labor and supplies, Humboldt mine, Morenci Branch, Phelps Dodge Corporation.

(Period covered: 1927 - 1928. Tons of ore hoisted: 140,000 per month. Mining method: Undercut block-caving.)

MINING

Year	Tons mined	Tons per man: Stoping[1]	Tons per man: Mine pay roll[2]	Tons per man: Overall[3]	Pounds powder per ton	Board feet timber per ton
1927	1,136,339	40.35	10.00	9.07	0.24	0.23
1928	1,483,984	62.76	11.84	10.45	.19	.25

1 Includes: (1) Boundary shrinkage stopes; (2) undercutting; (3) belling fingers; (4) chute tapping; and (5) stope repairs, but is exclusive of all development work.

2 Tons per man for shifts on mine pay roll, including men on salaries.

3 Tons per man for shifts charged to mining, including all labor from other departments, such as mechanical, electrical, carpenter, and other surface departments occupied on work chargeable to mining.

The output per man on present production and work associated with it, including all shifts on the mine pay roll with salaried employees for the year 1928, is approximately 18.5 tons. This excludes all lower level development which is for the purpose of bringing into production the next lower lift.

Table 2.- Summary of costs in units of labor and supplies, Humbolt mine, Morenci Branch, Phelps Dodge Corporation.

(Period covered: 1927 - 1928. Tons of ore hoisted: 140,000 per month. Mining method: Undercut block-caving.)

DEVELOPMENT

	Size of heading, feet	Feet per man shift		Pounds powder per foot		Board feet timber per foot	
		1928	1927	1928	1927	1928	1927
Grizzly drifts (raw)	4 by 6)	2.81	2.58	5.12	5.85	- -	- -
Supply drifts (raw)	6 by 8)			6.43	6.13	- -	- -
Motor drifts (raw)	8 by 9)	.98	1.26	10.87	8.01	- -	- -
Motor drifts (timbered)	10 by10)			9.37	7.50	- -	- -
Averages, total driving		1.52	1.93	- -	- -	- -	- -
Timbering drifts	6 by 8 or less	- -	- -	.82	.32	58.44	52.94
Timbering drifts	8 by 9 or over	- -	- -	1.08	.63	107.88	100.98
Averages, total driving and timbering		1.00	1.36	- -	- -	- -	- -
Finger raises (raw)	4½ by 4½)	5.71	4.84	3.82	4.83	- -	- -
Short haulage raises (raw)	4 by 6)			3.97	3.94	- -	- -
Long raises with dividers	4 by 7	1.47	1.49	5.97	8.25	28.18	16.54
Cribbed raises	4 by 7	1.10	1.73	4.83	2.96	84.20	62.71
Morenci slides	- -	- -	1.81	- -	5.15	- -	74.79
Averages, raises		3.91	3.48	- -	- -	- -	
Winzes		.42	- -	3.81	- -	52.53	- -
Grand Averages, all driving and timbering		1.71	2.35	6.36	6.91	61.53	40.28

Table 3.- Estimated cost of preparatory work for a block containing 120,000 tons, Morenci Branch, Phelps Dodge Corporation [a]

	Tons	Shifts	Units	Cost per unit				Total cost, labor, timber and explosives	
				Labor	Timber	Explosive	Total	Amount	Cost per ton
Supply drifts	600	87	130 ft.	$ 4.30	$ 2.20	$1.15	$ 7.65	$ 994.50	
Grizzly drifts	1,500	228	390 ft.	3.32	1.63	1.10	6.05	2,359.50	
Grizzlies	200	302	14 [b]	118.60	180.63	12.12	311.35	4,358.90	
Fingers	1,500	170	830 ft.	1.03	- -	.89	1.92	1,593.60	
Pilot raises	200	54	80 ft.	3.14	.73	1.36	5.23	418.40	
Shrink drifts	500	78	160 ft.	2.59	- -	1.07	3.66	585.60	
Totals	4,500	919	1,590 ft.					10,310.50	$ .086
Shrinkage stopes (tonnage used is swell only)	1,500	140	9,000 s.ft.	.10	- -	.08	.18	1,620.00	
Undercutting (tonnage used is from dog holes only)	3,300	336	10,000 s.ft.	.28	- -	.22	.50	5,000.00	
Totals	4,800	476						6,620.00	.055
Total above grizzly level	9,300	1,395	1,590 ft.	- -	- -	- -	- -	16,930.50	.141
Haulage drifts	2,500	286	330 ft.	5.86	1.99	1.42	9.27	3,059.10	
Loading chutes	300	119	7	73.04	104.70	5.02	182.76	1,279.32	
Haulage raises	1,300	207	600 ft.	1.56	.30	.72	2.58	1,548.00	
Total below grizzly lev	4,100	612	930 ft.	- -	- -	- -	- -	5,886.42	.049
Total development exc. of shrinks & undercut	8,600	1,531	2,520 ft.	- -	- -	- -	- -	16,196.92	.135
Grand total	13,400	2,007	2,520 ft.	- -	- -	- -	- -	22,816.92	.190

a Area = 10,000 square feet. Lift = 145 feet. Grizzly Drifts at 28-foot centers and Fingers at 14-foot by 18-foot, 8-inch centers. This estimate was originally made (April, 1928) to assist in planning operations for another mine of the Phelps Dodge Corporation.

b 7 single and 7 double grizzlies.

NOTE: All costs per ton are calculated on a basis of 120,000 tons production, unless otherwise noted.

Table 3.- Estimated cost of preparatory work for a block containing 120,000 tons, Morenci Branch, Phelps Dodge Corporation (Continued)

	Tramming		Hoisting		Sanitation		Ventilation		Assaying and sampling	
	Amount	Cost per ton	Amount	Cost per ton	Amount	Cost per ton	Amount	Cost per ton	Amount	Cost per ton
Supply drifts	$ 71.40		$33.40		$ 4.35		$13.92		$20.87	
Grizzly drifts	178.50		88.50		11.40		35.48		62.59	
Grizzlies	23.80		11.90		15.10		48.32		- -	
Fingers	178.50		88.50		8.50		27.20		- -	
Pilot raises	23.80		11.80		2.70		8.64		25.68	
Shrink drifts	59.50		29.50		3.90		12.48		25.68	
Total	535.50	$ .004	265.50	$ .002	45.95	$ .000	147.04	$ .001	134.82	$ .001
Shrinkage stopes (tonnage used is from swell only) ...	173.50		88.50		7.00		22.40		288.90	
Undercutting (tonnage used is from dog holes only)	392.70		194.70		16.80		53.76		- -	
Total	571.20	$ .005	283.20	$ .002	23.80	$ .000	76.16	$ .001	288.90	$ .002
Total above grizzly level	1,106.70	$ .009	548.70	$ .005	69.75	$ .001	223.20	$ .002	423.72	$ .004
Haulage drifts	297.50		147.50		14.30		45.76		52.96	
Loading chutes	35.70		17.70		5.95		19.04		- -	
Haulage raises	154.70		76.70		10.35		33.12		192.60	
Total below grizzly level	487.90	$ .004	241.90	$ .002	30.60	$ .000	97.92	$ .001	245.56	$ .002
Total development exclusive of shrinks and undercutting ...	1,023.40	$ .008	507.40	$ .004	76.55	$ .001	244.96	$ .002	380.38	$ .003
Grand total	1,594.60	$ .013	790.60	$ .007	100.35	$ .001	321.12	$ .003	663.28	$ .006

Table 3.- Estimated cost of preparatory work for a block containing 120,000 tons, Morenci Branch, Phelps Dodge Corporation (Concluded)

	Drills and tools		Operating supplies		Mine department expense		Grand total	
	Amount	Cost per ton	Amount	Cost per ton	Amount	Cost per ton	Amount	Cost per ton
Supply drifts	$ 179.40		$14.30		$ 78.00		$	
Grizzly drifts................	538.20		42.90		195.00			
Grizzlies	463.12		60.40		26.00			
Fingers	1,145.40		91.30		195.00			
Pilot raises	110.40		8.80		26.00			
Shrink drifts	220.80		17.60		65.00			
Total	2,657.32	$ .022	235.30	$ .002	535.00	$ .005	14,916.93	$ .124
Shrinkage stope (tonnage used is swell only)	1,100.40		143.00		195.00			
Undercutting (tonnage used is from dog holes only)	2,640.96		121.00		429.00			
Total	3,741.36	$ .031	264.00	$ .002	624.00	$ .005	12,492.62	$ .104
Total above grizzly level	6,398.68	.053	499.30	.004	1,209.00	.010	27,409.55	.228
Haulage drifts	455.40		36.30		325.00			
Loading chutes	77.98		23.80		39.00			
Haulage raises	828.00		66.00		169.00			
Total below grizzly level	1,361.38	$ .011	126.10	$ .001	533.00	$ .004	9,010.78	$ .075
Total development exclusive of shrinks and undercutting	4,018.70	$ .033	361.40	$ .003	1,118.00	$ .009	23,927.71	$ .199
Grand total	7,760.06	$ .064	625.40	$ .005	1,742.00	$ .014	36,420.33	$ .303

Table 4.- Mining Costs, Phelps Dodge Corporation- Morenci Branch, 1928

	Tons	Cost per ton			
		Labor	Explosives	Timber	Total
Stope Preparation:					
Drifts, driving, timbering, and tracks - - - - - - - - - -	--	.014	.004	.006	.024
Raises, includes grizzlies - - - - - -	--	.015	.005	.015	.035
General Development:					
Drifts, driving (haulage drifts) - -	--	.008	.002	-	.010
Drifts, timbering do do - - -	--	.010	.001	.014	.025
Drifts, tracks - - - - - - - - - - - - -	--	.003	-	-	.003
Raises, includes chute fronts - - -	--	.018	.005	.012	.035
Underground tunnel and chute repairs -	--	.008	-	.002	.010
Stoping:					
Breaking ground[1] and chute tapping -	--	.074	.034	-	.108
Stope repairs - - - - - - - - - - - - - -	--	.011	-	.010	.021
Total direct - - - - - - - - - - - - - - -	1,548,258	.161	.051	.059	.271
Average cost per ton - Compressed air, drills, tool sharpening, steel, water and sundry supplies (including handling and delivery) -	--	-	-	-	.045
Supervision	--	-	-	-	.040
Total extracting ore					.356

1/ Includes undercutting and shrinkage stopes.
2/ All costs based on total tonnage.

Circular No. 6108,
March, 1929.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

STATE REGULATIONS GOVERNING INSPECTION AND MAINTENANCE OF ELECTRICAL EQUIPMENT IN COAL MINES[1]

By L. C. Ilsley[2] and R. A. Kearns[3]

In Bureau of Mines Circular No. 6085, entitled "Mine Explosions in the United States during the fiscal year ending June 30, 1928" there is one of the most damaging indictments against the use of electricity in mines that was ever issued. As the charge stands, 14 of 30 explosions occurring in coal mines in a single year were of electric origin. Of a total of 340 fatalities 282, or 82 per cent, are charged against electricity.

Facing these facts, unwelcome as they must be to those who believe there is a future for electrically-equipped mines, the writers have examined anew the variou State codes to see wherein they may be lacking in providing proper legislation to govern the use of electricity in mines. There are many angles from which such an examination might be made, but, as indicated by the title of this paper, only the question of inspection and maintainance of electrical equipment and circuits has been considered at this time.

The indifference of several States to the need of electrical safety regulations in their safety codes is apparent. Again, in certain other States the space devoted to requirements covering the proper installation of electrical equipment is considerably in excess of that given to inspection and maintenance.

In this survey, use was made of the mine safety codes of the 24 States having a bituminous coal production of more than half a million tons each in 1926. The remaining States did not mine enough coal during 1926 to be listed separately by the coal division of the Bureau of Mines.

The States were first arranged according to the amount of their coal production, as one might naturally expect the larger coal producing States to have the best regulations. Secondly, the total number of pages in each mine safety code was noted. Next the percentage of this total which dealt with electrical equipment or wiring was found for each State. Finally the percentage of the total regulations which was given to the inspection or maintenance of electrical equipment was calculated for each of the 24 States. The results of the foregoing calculations have been tabulated in Table 1 which follows:

1 The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"

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Table 1.- Coal production, by States, and percentage of mining laws of each devoted to electricity.

State	Coal, tons	Mining laws, pages	Electrical regulations, percentage of total law	Inspection and maintenance of electrical equipment, percentage of total
Pennsylvania	153,041,638	161	17.6	1.95
West Virginia	143,509,340	62	9.8	0.63
Illinois	69,366,923	109	2.9	0.11
Kentucky	62,924,462	52	3.7	.73
Ohio	27,872,488	162	7.2	0.21
Indiana	23,186,006	78	4.3	0.17
Alabama	21,000,962	37	6.1	0.68
Virginia	14,133,386	29	1.5	0.21
Colorado	10,637,225	86	4.4	0.51
Wyoming	6,512,288	74	2.2	0
Tennessee	5,788,741	32	0.2	0
Iowa	4,625,487	29	3.8	1.86
Kansas	4,416,480	63	1.0	0
Utah	4,373,793	51	20.5	1.71
Maryland	3,078,353	89	5.0	0.75
Missouri	3,008,495	85	0	0
Oklahoma	2,842,673	30	2.9	0.15
New Mexico	2,817,923	15	2.7	0.75
Montana	2,797,760	28	1.6	0
Washington	2,586,568	91	13.2	2.03
Arkansas 1	1,459,017	84	0	0
North Dakota	1,370,244	47	1.8	0
Texas	1,091,158	16	8.8	.89
Michigan	686,707	13	1.7	0

1 Applies to both coal and metal mines.

Of the States listed, 8 were found lacking in any semblance of a specific regulation calling for inspection and maintenance of electrical equipment. Twelve others mention it sufficiently to avoid a zero rating, but not sufficiently to register 1 per cent of the total regulations devoted to safety matters. Four States, Iowa, Pennsylvania, Utah, and Washington, were found to have approximately 2 per cent of their regulations devoted to the inspection and maintenance of electrical equipment and wiring.

The specific regulations which have been found to bear either on maintenance or inspection have been abstracted from the various State codes and are quoted in full. Certain words referring to maintenance or inspection have been underlined. The quotations follow:

[illegible]

ALABAMA

Section 119

Rule 5. Electrical equipments installed shall not use any voltage higher than that in class one in or about working places. This does not prohibit the use of voltages defined in classes two and three (except in or about working places), provided such apparatus is installed and maintained according to these regulations.

Rule 21. Any unusual arcing, sparking, or heating of any of the electrical equipment shall be reported at once to the proper mine officer by the attendant or any other person having knowledge of the same.

COLORADO

Section 122 - Telephones

The owner shall provide and maintain an adequate telephone system from the surface, with convenient stations along and at the bottom of the shaft, slope or drift, and convenient to all double partings where trips are made up; provided, that more than twelve telephones shall not necessarily be installed in any one mine.

Section 123
(3d sentence)

All lamps shall be the property of the owner, and shall be kept in a room at the surface and delivered daily in good condition to the underground employees and others authorized to enter the mine. ....

ILLINOIS

Fire-Fighting Equipment in Coal Mines

5. (a) ....Telephone lines shall be constructed in a workmanlike manner and shall be repaired promptly when necessary.

INDIANA

Section 11 - Electricity--Motors and Wires

(C) All underground trolley wires shall be securely supported upon efficient and approved insulated hangers, and all trolley wires kept taut at all times.

IOWA

Telephone Systems

1306. In all mines where the working parts thereof exceed two thousand feet from the foot of the slope, shaft, or the mouth of drift as the case may be, a good and substantial telephone system or other like suitable means of communication shall be maintained at all times ready for use, from the bottom to some

suitable and convenient point at or near the face of such working parts which shall be extended as the works of the mine progress two thousand feet therefrom.

Grounding and Insulation of Current

1317. Electric pumps and stationary electric machines, shall be insulated and grounded in their emplacement, by the use of wires or other equivalent means and inspected with such frequency and kept in such repair that contact therewith will be rendered harmless in so far as possible, consistent with the use for which such machinery is intended.

Handling of Electrical Equipment

1318. It shall be unlawful for any person to inspect, repair, handle, disturb, or interfere with any of the electrical equipment or machinery of a mine except the mine inspector, operator, superintendent, mine foreman, or those designated by such persons to do such work, and those whom such designated persons may request or permit to aid in the work of handling or repairing.

KENTUCKY
Article IX
Safety Lamps--When to be Used.

2. ....The safety lamps used for examining any mine by an employee thereat or which may be used for working therein shall be provided by and be the property of the operator of the mine, and shall be in the custody of the mine foreman, or fire boss, or some competent person or persons designated by the mine foreman. Said person shall clean, fill, trim, examine and deliver said lamps, locked or sealed, and in safe condition, to the men who may have to use them, when they enter the mine........Electric lamps that have been tested and approved by the Federal Bureau of Mines may be used instead of safety lamps in which oil is used, except for purposes of testing for explosive gas.

MARYLAND

Section 97

The Bureau shall prescribe such regulations for the installation, maintenance, and operation of coal-cutting machinery, including periodic examinations thereof, adequate guarding of dangerous moving parts, protection from electric shock, and proper support of roof, and warning of bystanders, as may assure reasonable protection of persons who may be endangered by such machinery.

Section 118

Care shall be taken in installation and maintenance of telephone and signal lines to avoid and prevent grounds and crosses with circuits of higher potential, and to protect persons using such lines from injury.

Section 119

Systematic, periodic examinations and reports of the condition of all wiring and electrical equipment and apparatus shall be required by regulation of the Bureau, to be made by the operator, in all such mines.

NEW MEXICO

Section 3507 - Safety Provisions--Violation

(15) It shall be the duty of the operator to install and maintain a telephone system in every coal mine to such extent as may be reasonably required for the operation thereof.

OHIO

Section 934-2

Owner, lessee, or agent shall install telephone system.

Every owner, operator, lessee, or agent of a coal mine, where twenty or more persons are employed, shall install, and maintain in efficient working condition, a telephone connecting each main switch of such mine with an outside telephone so connected and maintained as to permit communication with persons outside of the mine with persons on the main switch or switches or other points inside of the mine that may be designated by the district mine inspector.

OKLAHOMA
ARTICLE VI

Section 5

.........All electric pumps inside of the mine shall receive careful attention while in use at a permanent pumping station. .....

PENNSYLVANIA
ARTICLE VI

Section 4

.........All such traveling ways shall be well drained, kept free from refuse of all kinds, and free from smoke, noxious gases, and electric wires, unless said wires are so placed and protected as not to endanger life and are kept in safe condition.

ARTICLE VIII

Section 1

The operator or the superintendent shall provide, and hereafter maintain in good condition from the top to the bottom of every shaft or slope, where persons or material are lowered or hoisted, a telephone or metal tube of proper diameter,

suitably adapted to the free passage of sound, through which conversation may be held and understood between persons at the top and the bottom of said shaft or slope; and he shall also provide means of signaling from the top to the bottom and from the bottom to the top of said shaft or slope. The same provision shall apply to inside planes whereon coal is lowered and persons have to travel, when required by the inspector. In all gaseous mines telephone connections shall be made from the surface to the main section of the mine. All signaling apparatus and telephone connections shall be kept in good condition and shall be always available for service. ....

ARTICLE XI

Section 1

1. All electrical apparatus and conductors shall be sufficient in size and power for the work they may be called upon to do, and, as hereinafter prescribed, efficiently covered or safeguarded, and so installed, worked, and maintained as to reduce danger from accidental shock or fire to the minimum, and shall be of such construction, and so worked, that the rise in temperature caused by ordinary working will not injure the insulating materials.

Ground Detectors

8. All underground systems of distribution that are completely insulated from earth shall be equipped with properly installed ground detectors, of suitable design.

The condition of such system as indicated by the ground detector shall be noted each day by the person in charge of the underground wiring, or by another competent person, who shall immediately report to him the occurrence of a ground.

Report of Defective Equipment

15. In the event of a breakdown, or of damage or injury to any portion of the electrical equipment in a mine, or of overheating, or of the appearance of sparks or arcs outside of enclosing casings, or in the event of any portion of the equipment, not a part of the electrical circuit, becoming alive, every such occurrence shall be promptly reported to the person in charge of electrical equipment.

Section 3 - Trailing Cables

56. Each trailing cable in use shall be daily examined by the machine operator, for abrasions and other defects, and he shall also be required to carefully observe the trailing cable while in use, and shall at once report any defect to the person in charge of electrical equipment.

57. In the event of the trailing cable in service breaking down, or becoming damaged in any way, or of its inflicting a shock upon any person, it shall be at once put out of service. The faulty cable shall not again be used until it has been repaired and tested by a properly authorized person.

Section 4 - Switches, Fuses, and Circuit-Breakers

61. Fuses shall be stamped or marked, or shall have a label attached, indicating the maximum current which they are intended to carry. Fuses shall only be adjusted or replaced by a competent person authorized by the mine foreman.

Section 5 - Motors

Motors in Gaseous Mines

67. In any gaseous portion of a mine, all motors, unless placed in such rooms as are separately ventilated with intake air, shall have all their current carrying parts, also their starters, terminals, and connections, completely enclosed in explosion-proof enclosures made of noninflammable material. These enclosures shall not be opened except by an authorized person, and then only when the power is switched off. The power shall not be switched on while the enclosures are open.

Enclosed Motors

70. All enclosed motors used underground shall be opened and thoroughly inspected by the person in charge of electrical equipment, or his assistant, at least once a week, and, where necessary, shall then be cleaned and repaired. Enclosed switches shall be opened and inspected at least once a month.

76. In any gaseous portion of a mine, if any electric sparking or arc be produced outside of a coal-cutting or other portable motor, or by the cables or rails, the machine shall be stopped, and not be worked again until the defect is repaired, and the occurrence shall be reported to an official of the mine.

Section 8

93. All portable devices for generating or supplying electricity for shot-firing, when in a mine, shall be in charge of the person commissioned to fire the shots.

Tests of Generators and Batteries

96. Frequent tests shall be made of all devices covered by rule ninety-three, to insure that their capacity has not been decreased by use or accident.

Article XXV

Rule Five - Duties of Motorman and Locomotive Engineer

........He shall see that the motors, cables, and controlling parts are kept clean and in a safe operating condition, and that the headlight is burning properly when the locomotive is in motion. ....

TEXAS

Mines--Requiring Owners and Operators of to Insulate Live Wires to Protect Persons and Animals

Section 1

................provided, however, it shall not be necessary to insulate or cover trolley wires, but they shall all be hung and kept not less than five feet and six inches above the rail, and shall be securely fastened, and not permitted to sag less than said height. ....

UTAH

Section 36 - Lamps in Gaseous Mines

(a) In any working place approaching any place where there is likely to be an accumulation of explosive gases, no light or fire other than safety lamps approved by the U. S. Bureau of Mines, shall be allowed or used. But, in all hydrocarbon mines only electric storage battery lamps shall be used for lighting purpose; the pattern of such lamp to be approved by the U. S. Bureau of Mines. Whenever such lamps are required in any mine they shall be the property of the owner or operator, and a competent person shall be appointed for the purpose of examining every such lamp, which examination shall be made as soon as possible before it is taken into the mine for use. He shall clean, lock, and otherwise ascertain if it is safe for use; provided, that all fire bosses or those who inspect the mine for the presence of explosive gases, must also personally examine their own lamps, and be responsible for their safe condition.

Section 39 - Locomotive and Trip Lights

(a) Each locomotive must be equipped with an efficient gong and with an efficient head light, both of which must be maintained in good operating condition. ....

Section 78 - Ground Detectors

All circuits, or groups of circuits, leaving switchboard in underground stations, and all circuits, or groups of circuits, leaving switchboard upon the surface and leading underground shall, if circuits are completely insulated from the earth, be equipped with ground detectors properly installed. Such detectors shall be inspected daily by a competent person, who shall report promptly to the superintendent of the mine the occurrence of any ground.

Section 85 - Transmission Lines and Cables

(d) Overhead Lines Above Ground. Overhead transmission lines between generating station or substation and the mine entrance, shall be supported upon insulators, which shall be adequate in quality, number, size, and design for the voltage transmitted. Where such line is more than five hundred feet in length,

lightning arresters shall be installed in connection therewith at the entrance to the mine. Such line, except in the case of trolley wires, shall be maintained not less than fourteen feet above the ground at the lowest point, except at the point of entrance to the mine.

(g) Lighting Circuits. Wires for all lighting circuits shall be covered with an insulation adequate for the voltage of the circuit, and, unless encased in pipes or other metallic covering, shall be strung on porcelain or glass insulators. Separate uncased wires shall be kept at least three inches apart, except where they enter the fittings. Metallic casings, if used, shall be efficiently grounded.

Section 86 - Fuses, Circuit Breakers, and Switches

(c) Fuses shall be stamped or marked, or shall have a label attached, indicating the maximum current that they are intended to carry. Fuses shall be adjusted or replaced only by an authorized and competent person.

WASHINGTON

Section 61 - Hoists and Hoisting

2. The operator or the superintendent shall provide, and hereafter maintain in good condition from the top to the bottom of every shaft or slope, at each alternate intermediate working level from or to which persons or materials are lowered or hoisted, a telephone or metal tube of proper diameter, suitably adjusted to the free passage of sound, through which conversation may be held and understood between persons at the top and bottom of said shaft or slope.

Section 131

In every working of a coal mine approaching any place where there is likely to be an accumulation of explosive gases, or in any working place where there is imminent danger from explosive gases, no light or lamp other than a magnetic locked safety lamp or electric lamp shall be allowed or used, except by superintendents, shot lighters or other certified men, who may use such lamps as may be approved by the mine inspector.

Whenever safety lamps are required in any mine they shall be the property of the owner of said mine, and a competent person who shall be appointed for that purpose shall examine every safety lamp immediately before it is taken into the workings for use and ascertain it to be clean, safe, and securely locked; and safety lamps shall not be used until they have been examined and found safe, clean, and securely locked.

Section 150

Report of Defective Equipment: In the event of a breakdown, or of damage or injury to any portion of the electrical equipment of a mine, or of overheating, or of the appearance of sparks or arcs outside of the enclosing casings, or in the event of any portion of the equipment, not a part of the electrical circuit, becoming alive, every such occurrence shall be promptly reported to the person in charge of the electrical equipment.

Section 152

19. Each trailing cable in use shall be daily examined by the machine operator, for abrasions and other defects, and he shall also be required to carefully observe the trailing cable while in use, and shall at once report any defect to the person in charge of electrical equipment.

Section 153

3. Fuses shall be stamped or marked, or shall have a label attached indicating the maximum current which they are intended to carry. Fuses shall only be adjusted or replaced by a competent person authorized by the mine foreman.

Section 154

2. Motors in Gaseous Mines: In any gaseous portions of a mine, all motors, unless placed in such rooms as are separately ventilated with intake air, shall have all their current carrying parts, also their starters, terminals and connections, completely closed in explosion-proof enclosures made of non-inflammable materials. These enclosures shall not be opened except by an authorized person, and then only when the motor is switched off. The power shall not be switched on while the enclosures are open.

6. In any gaseous portion of a mine if any electric sparking or arc be produced outside of a coal-cutting or other portable motor, or by the cable or rails, the machine shall be stopped and not worked again until the defect is repaired, and the occurrence shall be reported to an official of the mine.

Section 211

Duties of Motorman and Locomotive Engineer: The motorman or locomotive engineer shall keep a sharp lookout ahead, and sound the whistle or alarm bell frequently when coming near the parting switches or landings, and shall not exceed the limit allowed by the mine foreman. He shall see that the motors, cables, and controlling parts are kept clean and in a safe operating condition, and that the headlight is burning properly when the locomotive is in motion. He shall not allow any person, except his attendant, or mine officials, to ride on the locomotive or motor.

WEST VIRGINIA

Section 15

The operator, or agent, of every coal mine worked by shaft, shall forthwith provide, and hereafter maintain, a metal tube, telephone, or other approved means of communication from the top to the bottom of such shaft suitably adapted to the free passage of sound through which conversation may be held between persons at the top and at the bottom of the shaft; ....

Rule 22. Machine runners must take care of their machines and all parts thereof and cables and report promptly to the mine foreman or electrician any repairs necessary, ...

WYOMING

Section 1 - Telephone Equipment Required

There shall be a system of party line telephones installed, and kept in working condition by the coal company installing same, in each coal mine in operation in the State of Wyoming.

DISCUSSION OF REGULATIONS QUOTED

Pennsylvania's regulations regarding inspection and maintenance of electrical equipment in its bituminous coal mines are more comprehensive than those of any of the other States. Fourteen paragraphs were found dealing with different phases of maintenance or inspection. Near the beginning of Article XI, in Section One, there is found the word "maintained," which gives the State Inspection Department sweeping powers in regard to upkeep of electrical equipment. If this rule were strictly enforced there would be no complaints with respect to unsafe electrical conditions in Pennsylvania.

The other requirements refer to specific hazards. These are generally well considered and should prove very helpful in enforcing proper safety conditions with respect to electrical equipment.

Washington, with 8 paragraphs, ranks next to Pennsylvania in the number of subjects covered that relate to inspection and maintenance. Most of these rules are very similar to those of Pennsylvania. A strict enforcement of these regulations would have a marked effect on safety.

The third State in number of maintenance and inspection references is Utah, with a total of six. These rules are not so inclusive as those of Pennsylvania and Washington but should prove of aid to the State Inspector in promoting safe electrical practices in that State.

Maryland and Iowa each have three regulations. Iowa's regulations cover telephone systems and stationary electric equipment. Maryland requires maintenance of telephone and signal lines and, what is of more importance, "systematic, periodic examinations and reports of the condition of all wiring and electric equipment and apparatus." As far as is known, Maryland is the only State that requires periodic examinations and reports on electric equipment and wiring. Such a regulation, wisely enforced, ought greatly to increase electrical safety in mines.

Alabama, West Virginia, and Colorado each have two inspection or maintenance regulations. Eight other States have one such regulation to their credit. No inspection or maintenance regulation covering electrical equipment or wiring was found for any of the eight States which are given zero rating in Table 1.

SUMMARY

Nearly all of the States have evidently been negligent in providing suitable regulations covering inspection and maintenance of electrical wiring and equipment. In some of the laws, pages are devoted to minor safety questions, while the big question of inspection and maintenance of electrical equipment is passed by. Each year a number of States revise their codes. When could there be a better time than 1929 to place in the various State codes some adequate regulations covering maintenance and inspection?

While most of the State laws lack adequate regulations covering inspection and maintenance, one very encouraging step has already been taken in that four electrical inspectors were appointed by the Pennsylvania Department of Mines during the latter part of 1928. These inspectors have already covered a number of mines in their inspection and have been helpful in creating an interest for better upkeep of electrical mine equipment. Other States are considering a similar step and quite likely will follow the advance made by Pennsylvania.

LIST OF LAWS USED IN PREPARING TABLE 1

State	Title	Date of Last Issue or Amendment
Alabama	Mining Law of the State of Alabama	1928
Arkansas	State Mining Laws of the State of Arkansas	July 1919
Colorado	Coal Mining Laws, Colorado	1925
Illinois	General Mining Laws	Effective July 1, 1927
Indiana	Mining Laws of Indiana	In Force 1927
Iowa	State of Iowa Mining Law	1924
Kansas	Kansas Mining Laws	May 1918
Kentucky	The Mining Laws of the State of Kentucky	1920
Maryland	Mining Laws of the State of Maryland	1923
Michigan	Act No. 177 of the Public Acts Regulating the Operation of Coal Mines	1913
Missouri	State of Missouri General Mining Laws	1927

State	Title	Date of Last Issue or Amendment
Montana	Laws of Montana Administered by Industrial Accident Board (Bureau of Safety Inspection) Compiled from Revised Codes of 1921	Amendment of 1927
New Mexico	Mining Laws of New Mexico	(Approved March 17, 1919)
North Dakota	Mining Code of the State of North Dakota	1924. With Amendment of 1925
Ohio	Mining Laws of Ohio	1927
Oklahoma	Mining Laws of the State of Oklahoma	Approved April 4, 1927
Pennsylvania	Bituminous Mining Laws of Pennsylvania	1921. With Amendments of Apr. 7, 1925
Tennessee	Laws Governing and Regulating Mining in Tennessee; All Laws and Amendments thereto to 1921 included	1922
Texas	Coal Mining Laws of Texas	Effective Sept. 1, 1916
Utah	General Coal Mine Safety Order	1920. With Supplement of April 8, 1924
Virginia	Mining Laws of State of Virginia	1927
Washington	Coal Mining Laws of Washington	Amended 1919 and 1927
West Virginia	Mining Law of the State of West Virginia	Effective July 21, 1925
Wyoming	Coal Mining Laws of the State of Wyoming	1919. With Amendments of 1927

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THE NATIONAL SAFETY COMPETITION TO ASSIST IN THE REDUCTION OF MINE AND QUARRY ACCIDENTS

BY

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THE NATIONAL SAFETY COMPETITION TO ASSIST IN THE REDUCTION OF MINE AND QUARRY ACCIDENTS[1]

By W. W. Adams[2]

For the past four years the United States Bureau of Mines has conducted a safety contest in which approximately 300 mines and quarries - representing 30 of the 48 States - have participated yearly. This contest, which is designated the "National Safety Competition," has for its underlying purpose the promotion of safety in the mineral industry and the development of friendly rivalry among the competing companies.

The immediate object of the contest is the winning of a trophy known as the Sentinels of Safety, which portrays in bronze a mother and child greeting the father upon his safe return from work. The name of the mine or quarry which wins the right to hold the trophy for a year will be engraved on the front of the pedestal. There are five of these trophies, presented by the Explosives Engineer magazine.

Whenever a company wins the trophy a formal presentation ceremony is held. At these exercises, all of the officers and men connected with the winning plant, as well as a representative of the Bureau of Mines, are present. The bronze trophy is presented to the company and a certificate issued by the Bureau of Mines is awarded to each employee whose untiring efforts contributed toward the victory of his mine. Thus there is public recognition of the fact that only by close and hearty cooperation of employer and employee can safety be most effectively promoted.

Our former Secretary of Commerce, the Honorable Herbert Hoover, now President-Elect of the United States, has sent a personal letter of congratulation to the winning companies at the close of each year's contest. His personal interest in this subject has been an inspiration to those of us on whose shoulders the conduct of the contest has rested.

The scope of the contest is indicated by the volume of exposure to hazard, as represented by the number of man hours worked each year. The first year's contest represented 68 million man hours of work, the second 95 million man hours, and the third 92 million man hours; this means about 28 thousand men were represented the first year, 40 thousand men the second year, and 38 thousand men the third year.

1 Read by permission of the Director, U. S. Bureau of Mines, before a meeting of the Coal Mining Institute of America, Pittsburgh, Pa., on Dec. 12, 1928.

2 Supervising statistician, U. S. Bureau of Mines.

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Approximately 80 per cent of the companies entering the contest are able to remain throughout the period. The present year's enrollment of 322 plants exceeds that of any previous contest.

Companies that enroll in the contest are divided into five groups according to the commodities produced; that is, they are classified under anthracite coal mines, bituminous coal mines, metal mines and nonmetallic mineral mines, quarries and open-pit mines.

The National Safety Competition considers the accidents of all employees, both surface and underground, but eligibility in the contest is confined to those mines that employ 50 or more men underground and to quarries or open-pit mines which have 25 or more men in the pit. All mines and quarries must operate for at least 150 days of the year.

Each contestant agrees to furnish the Bureau of Mines with a report of each individual accident that disables an employee beyond the day of the accident. A carbon copy of the report which the company furnishes to the State Industrial Commission is sufficient. In addition to the accident reports, each company furnishes monthly reports of the number of man hours worked. This last item is used as a basis for calculating the accident rates which determine the relative standing of the various companies.

More than 100 coal mines were enrolled in the contest for the present year. The results of their safety efforts will be announced early in the new year.

The annual safety contests began in 1925. In that year 94 coal mines were enrolled and 59 succeeded in remaining in the race until the close of the year. For various reasons some of the companies had to drop out, and others were eliminated because of incomplete accident records. The enrollment for the second year was the same as in the first year, but 78 instead of 59 mines continued until the close of the contest period. In 1927, the third year, the enrollment showed 95 coal mines, 68 of which remained until the close of the year. The present year, 1928, with an enrollment of 114 coal mines, including 90 bituminous mines in 11 States, should show a larger number of companies completing the contest period than any previous year.

One of the conspicuous facts revealed by the National Safety Competition is that most mines and quarries have much better safety records than one might be led to believe from the accident rates that are so widely broadcast over the country. The stone-quarrying industry offers a striking illustration of this fact. Eighty-six per cent of the quarries that took part in the 1927 contest had safety records which were better than the average for the quarry group. That is to say, while the average accident-severity rate for all quarries was 4.4, 86 per cent of the individual plants had accident-rates that were less and therefore better than this figure, and only 14 per cent had accident-rates which were higher.

Similar, but less striking, was the record for bituminous coal mines. Sixty-two per cent of the bituminous mines last year had rates that were better than the group rate, and 38 per cent had rates that were worse than the group average. In the contest of two years ago, 69 per cent of the bituminous mines had favorable rates, as against 31 per cent having unfavorable rates.

What has been said of quarries and bituminous coal mines was also true to a greater or less degree of metal mines, nonmetallic-mineral mines and anthracite mines.

Attention is directed to the remarkable safety records of some of the companies as they have been revealed by the National Safety Competition. The United States Coal and Coke Co. operates several coal mines at Gary, in the southern part of West Virginia. That company has won the trophy three years in succession; its No. 6 mine was the winner in the first and second year's contests, and its No. 2 mine was the winner in the third year. In the first year, No. 6 mine, in which more than 300 men were employed, had only 11 accidents. All of them were comparatively slight, as they resulted in only 122 days of disability. The accident-severity rate for this mine was only 0.3, whereas the rate for all of the bituminous coal mines was 10.2. In the following year the same mine had an accident rate of only 0.2 as against 10.7 for the whole group. In the third year No. 2 mine of the same company was the winner, with an accident rate of only 0.1 as compared with 15.7 for the whole bituminous group. A Pennsylvania coal mine, the Clearfield Bituminous Coal Corporation's mine at Rossiter, Indiana County, Pa., was given honorable mention in the first year's contest. That mine's accident-severity rate was 0.7 as compared with the group rate of 10.2. All of the bituminous mines that won honorable mention in the second year's contest were mines situated in West Virginia and were operated by the United States Coal and Coke Co. The same company won three out of the four awards of honorable mention in the third year's contest; the fourth award was won by the Panther coal mine operated by the United States Fuel Co. at Heiner, Utah.

The records from which these instances are cited are thoroughly dependable, as they have been certified for completeness and accuracy by each of the companies concerned. The records indicate how nearly perfect, from the standpoint of safety, a coal mine can be made.

What has been said of bituminous coal mines might also be said of quarries and other types of mines. For example, the trophy for the metal mine group in 1925 was awarded to a zinc mine operated by the New York Mining Co., at Picher, Okla., for having an accident-severity rate of only 0.2 as compared with a rate of 9.1 for the whole metal-mine group. An even better record was established by the winners of the next two annual contests in the metal-mine group. The trophies in these two years were awarded to metal mines that were operated without a single lost-time accident. The 1926 trophy was awarded to the Federal Mining and Smelting Co.'s lead and zinc mine at Baxter Springs, Kans., and the 1927 trophy was awarded to the Bristol iron-ore mine at Crystal Falls, Mich., operated by the Bristol Mining Co. In the field of nonmetallic mineral mines, the winners of the contests during the past three years were a gypsum mine at Gypsum, Ohio, operated by the

United States Gypsum Co., a gypsum mine at Grand Rapids, Mich., operated by the Beaver Products Co., and the Marquette Cement Manufacturing Co.'s limestone mine at La Salle, Ill. In the last two years the winning mine in this group was operated with no lost-time accidents whatever.

The trophy winners in the quarry and open-pit mine groups were the Security limestone quarry of the North American Cement Co., at Security, Md., another limestone quarry operated by the same company at Martinsburg, W. Va., and the Mitchell limestone quarry operated by the Lehigh Portland Cement Co. at Mitchell, Ind. As only one company can win the prize, special recognition or honorable mention is given to the companies ranking second, third, fourth, and fifth in the competition. This recognition is in the form of a letter from the Director of the Bureau of Mines advising the company of its high rank in the competition. In addition to this, honorable mention is also given to any company that operates its plant throughout the year without a single lost-time accident. There is perhaps no better way of securing and maintaining close cooperation between a company and its employees in the realm of accident-prevention than by joining in such an endeavor as that afforded by the National Safety Competition.

Coal mining is the largest single branch of the mineral industry in the United States; it employs three quarters of a million men as compared with one-quarter of a million men employed in all other mines and quarries. Yet coal mining, important as it is, has no uniform records of the 150 thousand or more nonfatal injuries that occur every year. Records of fatal accidents are fairly well maintained by the State mine inspectors and by the United States Bureau of Mines through the cordial cooperation and assistance of the State inspectors. It is in the class of nonfatal injuries that the potential accidents of mining can best be studied with a view to their prevention. The average nonfatal injury disables the workman for 15 days and represents an average production loss of 60 tons of coal. It is probable that the yearly loss of production from temporary injuries alone represents a tonnage of not less than 20 million dollars' worth of coal. These losses can be reduced, but to bring about the reduction requires more than well-intentioned safety efforts. Definite records of accidents should be kept for the whole industry so that standards of progress may be established and every company may be enabled to learn whether its individual accomplishments toward safety compare favorably or unfavorably with that of the industry as a whole. Such records should be made available to the smaller producers who lack the resources of some of the larger companies to carry on their safety studies independently. The cooperation of the larger companies is therefore needed and is earnestly desired for the benefit of the industry as a whole.

In the absence of uniform records for the entire coal industry, the National Safety Competition has made available uniform and comparable accident records for a small part of the industry--a very small part, indeed, but one which should grow from year to year. So far as I know, these are the only records covering all accidents causing lost time amounting to one day or more that are prepared in such a way as to make possible a fair comparison of the accident rate of one State with that of another State and at the same time to establish a general basic rate as a standard for all mines.

Inasmuch as the National Safety Competition comprises the records of coal mines, metal mines, and stone quarries from the various States, it will lay a foundation for determining the true relative hazards between the States and their different kinds of plants. This information should be useful in helping to develop more equitable insurance rates for the different branches of mining. That is to say, the records will help to develop the mathematical constants which determine the fixing of accident-insurance rates. With these constants established, the relative cost of accidents may be determined, for it should be said that insurance figures now available do not reveal the true relative hazards as between industries in different States. Such statistics do not purport to show more than the actual receipts and disbursements on account of accidents. The true costs of accidents, as distinguished from the actual payments made on account of them, are basic and should be portrayed in their true proportions without reference to changes in the compensation laws of the different States and without reference to variations in the wage scales of the employees.

At the present time the difficulty, if not the impossibility, of comparing the frequency of accidents in one State with that in another State, is shown by a study of the classes of nonfatal injuries covered in the yearly reports published by a few of the State inspection departments. The reports published by the Pennsylvania Department of Mines cover only injuries that cause 60 or more days of disability. This means that more than 90 per cent of the injuries which are probably taking place are not covered by the published figures of that department. If accident rates were calculated on the published figures only they would appear extremely low and would reflect a very small part of the injuries that are actually occurring. The West Virginia Department of Mines also publishes figures that appear to omit many lost-time injuries. The Illinois reports apparently cover only 7-day accidents, which means that more than 30 per cent of the injuries are omitted. The report for Alabama contains no statistics of nonfatal injuries.

In this connection it is observed that when a State inspector's annual published report fails to show the number of injuries causing only 1 day of disability, the report is in that respect 6 per cent incomplete; that is, 6 per cent of the injuries have been left out. If the report omits 1 and 2 day accidents, it is 12 per cent incomplete. If all accidents of less than 7 days' disability are omitted, the report is 36 per cent incomplete. If accidents causing less than 10 days' disability are omitted, the report is about 50 per cent incomplete, and if only 30-day-and-up accidents are counted, then the report is more than 85 per cent incomplete. It is obvious, therefore, that whenever an injury rate is mentioned, care should be exercised to state what class of injuries are included, so that the injury rate may be clearly understood.

These illustrations indicate how fragmentary the records of nonfatal injuries at coal mines are at the present time - a condition for which the State inspectors are not necessarily responsible. Many of the inspectors are handicapped by inadequate personnel and finances to handle the volume of work which complete reports of nonfatal injuries would entail. Yet as long as human beings are injured in large numbers it should be somebody's business to gather together all obtainable information on this subject with a view to focusing attention on the scope of

the problem and on its various phases, so that the accident-prevention engineers at coal mines may have at hand the essential data needed to cope properly with the subject. The National Safety Competition is a small contributor in this respect, but it is suggestive of what might be undertaken toward establishing complete records of injuries in the coal-mining industry of the United States.

Now as to certain features of a safety contest such as the National Safety Competition. First of all, the contest places all mines on an equal basis as regards opportunity to win the prize, at least as far as it is physically possible to place all mines on an equal footing. Second, the method of determining the winner is absolute and free from uncertainties due to differences in human judgments. It is, as far as practicable, placed on an exact mathematical basis. Personal opinion plays no part in arriving at a decision, except in the case of a tie between two or more companies. Third, the contest utilizes and capitalizes the natural instinct and desire of a man to surpass his fellows in any undertaking. It is natural that each company should strive to win the prize because that prize denotes success and leadership in the prevention of accidents. Thus the natural human attribute of ambition is brought into play in a most useful direction. Fourth, the records which the competing companies furnish to the Bureau of Mines for purposes of the contest constitute a valuable source of information as to the causes of accidents in the mining industry.

The mining industry must be credited with being among the first major industries in the United States to undertake, in a systematic manner, the prevention of accidents. It must now be credited with being among the first to intensify that effort on a national scale, as it has been doing for the past four years in the National Safety Competition for the Sentinels of Safety trophy. It is to such organizations as the Coal Mining Institute of American that the coal industry is indebted for being placed in a position of leadership in safety work more than two generations ago and for maintaining that leadership on a national scale down to the present day.

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